METAL PROGRESS

1950

THIS ISSUE

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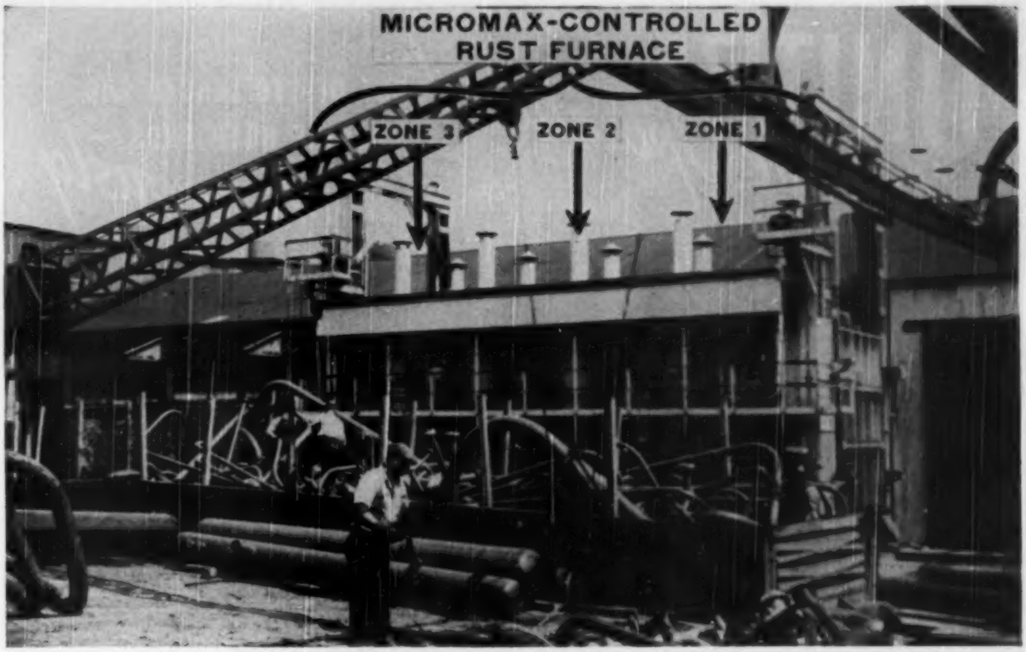


Fabricated Piping is annealed by Benj. F. Shaw Co., Wilmington, Del., in the Micromax-controlled furnace. Close control prepares pipe for high-temperature, high-pressure service.

Contractor Meets Insurance Specs with Micromax Control

In operating their new heat-treat department, the Shaw organization faces two typical piping-contractor's conditions. First, they require high-quality results to meet their own standards; Second, their customers require air-tight proof of such results, for insurance and other reasons.

Micromax control, with record of each individual zone's temperature, helps metallurgist exercise close supervision of all temperatures throughout the anneal of Shaw piping.

To handle both situations, Shaw selected a heat-treating team of versatility and dependability. They got an outdoor-type, oil-fired, car-bottom furnace and equipped it with Micromax Electric Control Pyrometers for fully-automatic temperature regulation.

The furnace accommodates both the big, intricately-formed welded piping, and the flanges and other fittings, which Shaw supplies to power plants and other industrial establishments. For uniform temperature distribution in so large a furnace, handling so wide a variety of loads, the fuel-oil firing system is divided into 3 zones, as shown in the photo above. Instrumentation of the Furnace provides each zone with its own Micromax Recording Controller. These 3 instruments not only regulate the fuel in proportion to demand, but also reset the equipment to maintain the correct temperature both when the furnace load changes, and when it is in effect changed by fluctuations in fuel, or in outside temperature, wind direction, etc. This instrumentation more than meets the first requirement—for high-quality results.

To meet the second requirement—proof of temperature-control results—Shaw has all three of the zone temperatures additionally recorded as one curve, by a Micromax 3-point instrument. This pyrometer's chart goes with the job to the purchaser of the piping, and demonstrates to the purchaser the quality of heat-treatment. As a Shaw man said, "It's absolutely essential that we use accurate, reliable controls. And we have them, in Micromax."

For further Micromax information, ask us to send Catalog ND44(1). Leeds & Northrup Co., 4927 Stenton Ave., Philadelphia 44, Pa.

MEASURING INSTRUMENTS · TELEMETERS · AUTOMATIC CONTROLS · HEAT-TREATING FURNACES

LEEDS & NORTHRUP CO.

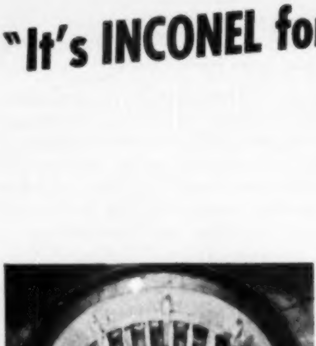
Jrl Ad ND44-33A-626(1)

Metal Progress is published and copyrighted, 1950, by American Society for Metals, 7301 Euclid Avenue, Cleveland, Ohio. Issued monthly; subscriptions $7.50 a year. Entered as second-class matter Feb. 7, 1921, at the post office at Cleveland, Ohio, under the act of March 3, 1879.

Pit-type furnace with all-Inconel radiant tube assembly. Designed and built by Surface Combustion Corporation, Toledo 1, Ohio.

With Surface Combustion Corporation, too—

"It's INCONEL for longer-lasting furnace equipment!"



A pit-type furnace with an Inconel atmosphere generator sheath. The Inconel sheath was still in good condition after 17 months of service despite severe operating conditions. Manufactured by Surface Combustion Corporation, Toledo 1, Ohio.

They tried Inconel® first in an atmosphere generator sheath . . . exposed to a controlled atmosphere and severe temperature.

17 months later, when the furnace was overhauled, they found the Inconel sheath still in good condition.

Impressed by this performance, Surface Combustion Corporation engineers ordered all-Inconel radiant tubes installed in a pit-type gas carburizing furnace. The fabrication job was not difficult because Inconel is readily available in seamless extruded *thin-walled* tubing and fabricated return bends.

The tubes were assembled to the return bends by welding... practical because welds in Inconel are as heat- and corrosion-resistant as Inconel itself.

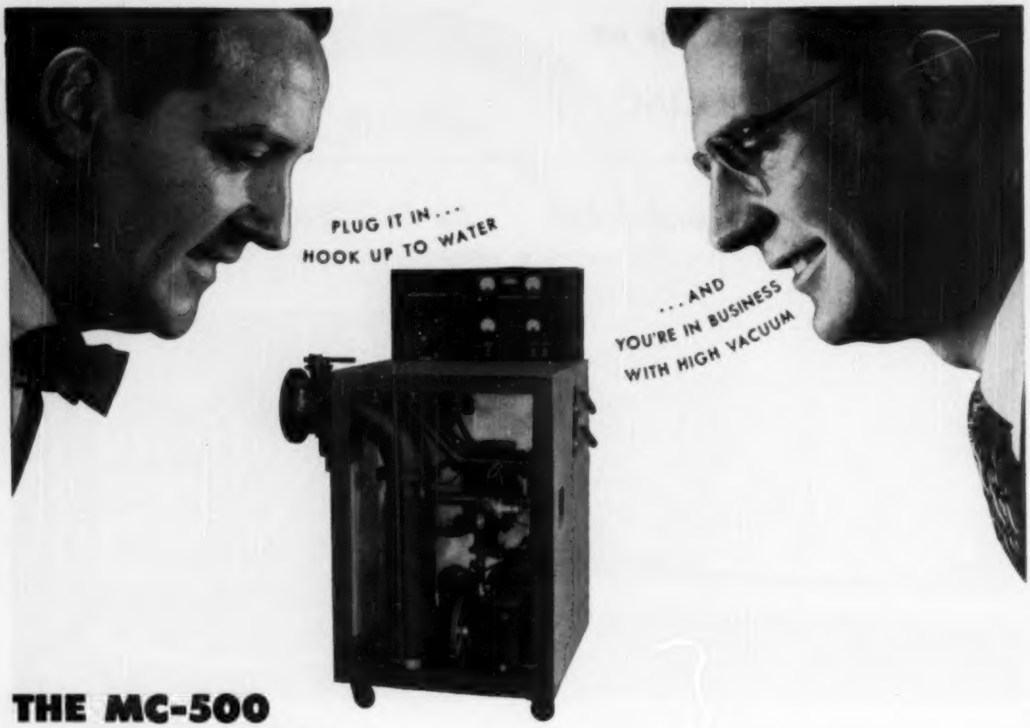
Like Surface Combustion, many other large makers of heat-treating equipment have turned to Inconel for extra service life and lower maintenance costs. Inconel has long ago established itself as one of the most durable high-temperature metals available at any price. Exposed to temperatures of up to 2200° F., Inconel resists corrosion, embrittlement, and destructive oxidation.

For further information about fabricated Inconel radiant tube assemblies, write directly to INCO. Your nearest INCO distributor will gladly quote on stock Inconel mill forms.

THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street, New York 5, N. Y.

EMBLEM OF SERVICE INCO TRADE MARK

INCONEL . . . for long life at high temperatures



THE MC-500 EXHAUST UNIT

. . . another DPi High Vacuum "Packaged" Unit that cuts pumping costs

Plug this compact unit into an ordinary 60-cycle, 115-volt a-c line, hook up the water connections, and the MC-500 does the rest!

- Handles large volumes of continuously evolved gas at pressures of less than one micron Hg.
- Evacuates a four-cubic-foot volume in about five minutes.
- Ultimate vacuum is approximately 10^{-5} mm. Hg at 25° C.
- Unit includes a 5-liter-per-second mechanical pump to produce the primary vacuum in the system and to back the diffusion pump. Also a 1-liter-per-second mechanical pump to maintain vacuum in the diffusion pump while the larger mechanical pump is roughing.
- Complete control system of switches, transformer, and automatically operating protective valves on the water lines.
- Two-station Pirani gauge and an ionization gauge to indicate pressures at a glance.
- Quick-acting high vacuum valve with attached air inlet valve for venting system without shutting off diffusion pump.

For information about the application of the MC-500 Exhaust Unit to your specific problems write Vacuum Equipment Department, ***Distillation Products Industries,*** 753 Ridge Road West, Rochester 3, N. Y. (Division of Eastman Kodak Company).

DPi

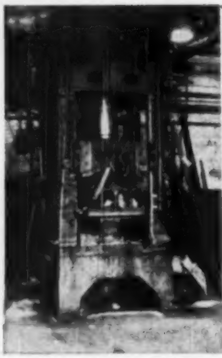
high vacuum research and engineering

Also . . . vitamins A and E . . . distilled monoglycerides . . . more than 3300 Eastman Organic Chemicals for science and industry.

Light Metals Die Casting
HOTFORM
HOTFORM die for production of typewriter part. 301,948 pieces and condition still excellent!
Hotform is designed, by chemistry and fabrication, to overcome the troubles encountered in building die casting dies. If you have experienced poor machinability (perhaps pins do not fit easily in reamed holes)—or if movement in hardening has been a problem—or if you have had die failures due to cracks and breakage from thermal or mechanical shock—USE HOTFORM!
Strong and tough at elevated temperatures, Hotform is carefully annealed and inspected, supersonically tested in large sizes. Hotform is available from stock in all die casting die sizes, and also in drill rod form for pins, guides, cores, etc. Our representatives will gladly assist you with the application and heat treatment of Hotform for your work.
Vanadium-Alloys
STEEL COMPANY
Latrobe, Penna.
Manufacturers of
FIRST QUALITY
TOOL AND DIE STEELS
exclusively

MOLTEN METAL won't affect LUMNITE* heat-resistant floors . . .

When 2800°F. molten metal occasionally spills from lift-truck ladles onto this foundry floor, Lumnite heat-resistant concrete withstands the thermal shock. The 1750-sq.-ft. floor is constructed with a 5¼-inch-thick slab of Lumnite-trap rock heat-resistant concrete and a ¾-inch topping of tough, wear- *and* heat-resisting Lumnite-emery concrete. This Lumnite heat-resistant concrete floor made possible a change-over from dirt floors . . . permitted handling ladles with lift-trucks. Such concrete floors made with Lumnite calcium-aluminate cement may be quickly and easily installed with a minimum of outage time, because Lumnite concrete reaches service strength in 24 hours or less. For further information write to Lumnite Division, Universal Atlas Cement Company (United States Steel Corporation Subsidiary), Chrysler Building, New York 17, New York.



Time Saved, Cost Cut

in installing the bed for this 300 ton hydraulic press. Bed is 8′ by 8′ by 1½′ thick. The press was moved, foundation dug out of dirt floor, new foundation poured with Lumnite and ordinary concrete aggregate bed, and the press put back in place in less than 24 hours! Time off the job was kept to bare minimum. And maintenance costs are next to nothing for durable Lumnite concrete.

. . .

Heat-resistant floor and hydraulic press bed at Minneapolis-Moline Co., Hopkins Plant, Minneapolis, Minn.

SPECIFY CASTABLE REFRACTORIES MADE WITH LUMNITE

"LUMNITE" is the registered trade mark of the calcium-aluminate cement manufactured by Universal Atlas Cement Company.

MP-L-26

LUMNITE — A UNIVERSAL ATLAS PRODUCT — **FOR REFRACTORY CONCRETE**

NBC SUMMER SYMPHONY CONCERTS—*Sponsored by U. S. Steel Subsidiaries—Sunday Evenings—June to September*

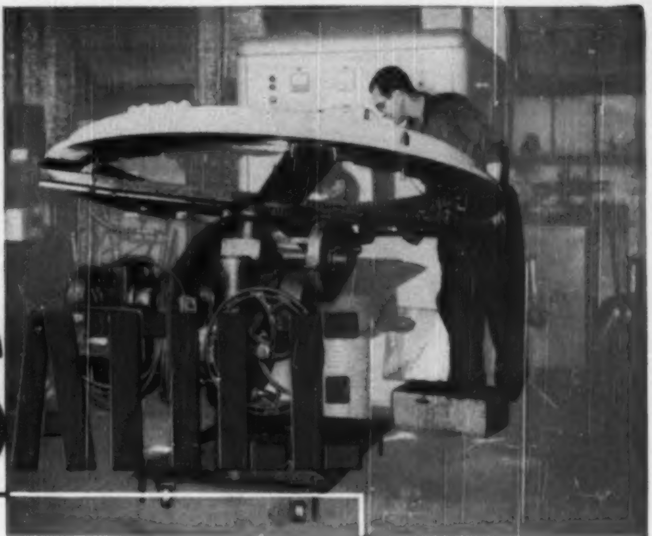
SEVEN STRONG REASONS explain the trend to N-A-X HIGH-TENSILE steel in the manufacture of commercial vehicles.

50-NAX-5

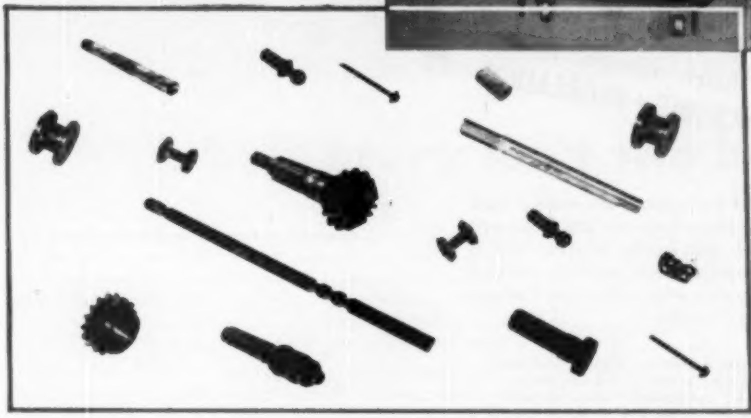
GREAT LAKES STEEL CORPORATION N-A-X ALLOY DIVISION • ECORSE, DETROIT 29, MICH. • UNIT OF NATIONAL STEEL CORPORATION


M.D.

VERSATILE



"Internal ring gear being hardened on the Lindberg LI-25 Induction Heating Unit".



Investigate the amazing versatility of the Lindberg Induction Heating Unit—approximately 2000 different parts have been selectively hardened or annealed on this typical commercial heat treating installation.

FROM THE LARGEST—The internal ring gear illustrated above—with a 60" inside diameter, 3½" face with 187 teeth each individually heated and oil spray quenched.

TO THE SMALLEST—This small 2" stamped metal rocker arm was selectively heated and water quenched on the small square face at the rate of 3000 per hour. Investigate this versatile Lindberg Induction Heating Unit—it may supply the answer to your selective heating operations.

SPECIFY LINDBERG

for any heat treating or melting need! Lindberg manufactures every type and many sizes of melting and heat treating furnaces from tiny laboratory units to mammoth field erected installations—whether it's gas, oil, electric, arc, low or high frequency—consult your local Lindberg Office!

LINDBERG
HIGH FREQUENCY DIVISION

LINDBERG ENGINEERING COMPANY 2448 W. Hubbard Street, Chicago 12, Illinois

GO "AUTOMATIC" ... save money...

in controlling bath temperatures for PLATING • PICKLING • DEGREASING

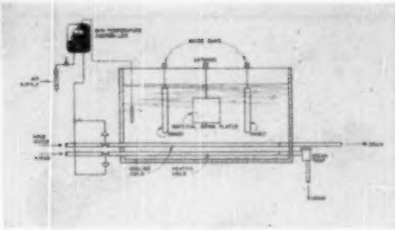
It takes only a few degrees variation from correct bath temperature to make the difference between fine finish with cost *savings*, and poor finish with costly *wastes*. That is why it is real economy to replace undependable manual control of finishing temperatures with *automatic* Foxboro Control. Here are typical advantages:

Plating — Temperatures a few degrees too high or low can produce dull, lustreless, off-color, brittle, or streaked plating. The Foxboro M-41 Controller automatically holds temperature so close to optimum that faults due to temperature variations are entirely eliminated.

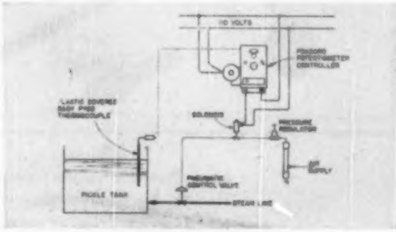
Pickling — Foxboro Automatic Control of strong acid pickling bath temperatures conserves both acid and steam by eliminating overheating and boiling. It increases production and quality from the unit by maintaining the optimum high temperature.

Degreasing — Automatic Foxboro Control of degreaser temperature insures proper vapor level, prevents loss of vapors over top edge of the tank. This also reduces the hazard to health of operators due to boil-over.

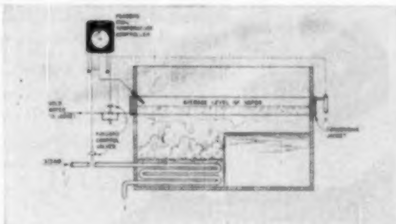
Whatever your finishing bath may be, maintaining proper temperature is a problem which has only two solutions: automatic temperature control; or constant, manual attention by the plating room operators. Foxboro Automatic Temperature Control does it easier, less expensively, and more dependably! Write for technical recommendations on your operations. The Foxboro Company, 52 Neponset Ave., Foxboro, Mass., U. S. A.



Chromium Plating bath temperature control



Strong acid pickling bath temperature control



Solvent degreaser temperature control

FOXBORO
REG. U. S. PAT. OFF.

Instruments that improve product uniformity

This hole story isn't the half of it!

If you're redesigning to cut the cost of hollow parts you can do it around the hole in Timken® seamless tubing. By using Timken tubing instead of bar stock you eliminate the drilling operation. The hole is already there. Finish boring is often your first production step. There's less stock to machine, less scrap loss. Parts cost less to make.

But that isn't the half of it! By using Timken tubing you get increased product strength as well as lower product cost. That's because the piercing process by which Timken tubing is made is basically a forging operation. The tube is thoroughly hot worked during piercing, resulting in a uniform spiral grain flow for greater strength and a refined grain structure which brings out the best in the quality of the metal. And you get uniform response to your machining and heat treating operations from tube to tube and heat to heat—thanks to Timken's rigid quality control from melt shop through final inspection.

You can get *extra* savings from Timken seamless tubing by always using our free tube engineering service. This service gives you the most economical tube size for your job—guaranteed to clean up to your dimensions. You're sure of minimum machining time and maximum saving of metal.

Write today for an analysis of your requirements. Ask, too, for your free copy of our informative 52-page booklet "A Handbook of Seamless Steel Tubing". The Timken Roller Bearing Company, Canton 6, Ohio. Cable address: "TIMROSCO".

YEARS AHEAD—THROUGH EXPERIENCE AND RESEARCH

Specialists in alloy steel—including hot rolled and cold finished alloy steel bars—a complete range of stainless, graphitic and standard tool analyses—and alloy and stainless seamless steel tubing.

Users report savings up to 56% with Aluminum Fasteners

Marked economies through the adoption of aluminum fasteners are reported by customers of the Aluminum Company of America in a broad range of industries. Savings up to 56% are cited for certain types of aluminum fasteners.

Alcoa Announces New

ECONOMY BOLT

A new hex head Economy Bolt, available at prices only slightly higher than machine screws, is announced by Alcoa. A semi-finished regular machine bolt, the Economy Bolt is available in sizes from 10-24 to ¾"-10. Like other fasteners in the Alcoa line, it is made of high strength Alcoa 24S-T4 Alloy. Threads are class 2, free fit, and conform to American Standards Association specifications.

ALUMINUM FASTENERS SOLVE CORROSION PROBLEM FOR WEATHER-EXPOSED PRODUCTS

For lawn furniture and other products which will be exposed to weather, Alcoa Aluminum Fasteners will prevent disfigurement by rust streaks. Because they resist corrosion, they also facilitate easy disassembly of the product for storage.

Alcoa Fasteners are usable with aluminum, wood and other non-metallic materials, in the following types: machine screws, wood screws, machine bolts, hex, wing and cap nuts, standard, lock and finishing washers. A wide variety of head types and sizes is available, with both slotted and Phillips recess heads.

Utensil Manufacturer Solves Rust Problem with ALCOA ALUMINUM FASTENERS

To make a good product better—you can't go wrong with Alcoa Aluminum Fasteners. Take the case of the utensils made by the Mardigian Corporation, whose aluminum utensils were excellent except that plated fasteners in the handle assembly rusted in use. Mardigian eliminated all rust problems by switching to Alcoa Aluminum Fasteners—lowest cost corrosion-resistant fasteners they—or you—can buy.

WRITE FOR FREE SAMPLES

Why not see how lustrous Alcoa Aluminum Fasteners can help dress up your product and eliminate corrosion problems? Simply write us, on your letterhead; specify the types and sizes you're interested in, and we'll send you the samples by return mail. Write to ALUMINUM COMPANY OF AMERICA, 2135H Gulf Bldg., Pittsburgh 19, Pa.

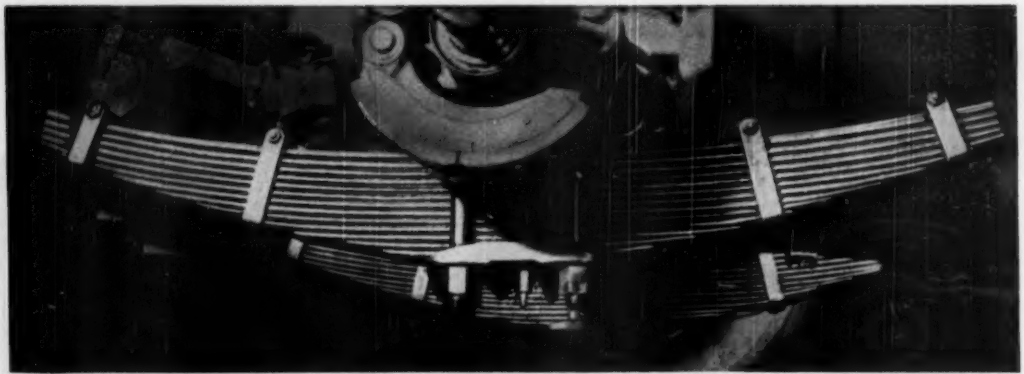
THE LOWEST-COST CORROSION-RESISTANT FASTENERS ARE

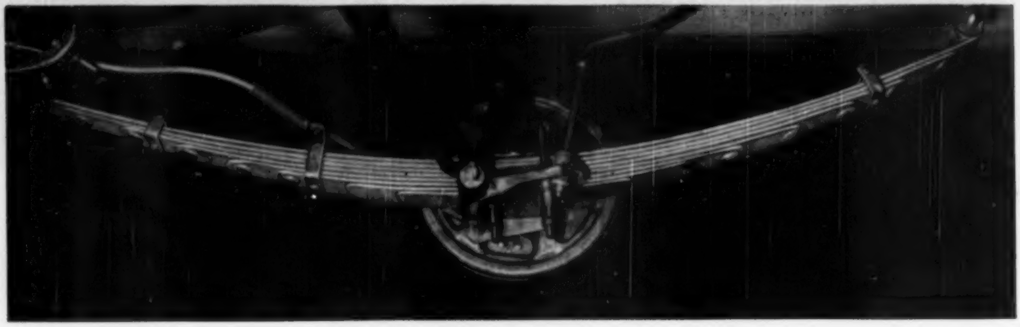
ALCOA *Aluminum* FASTENERS

..."well, Jim, when I buy salt I expect service—and I get both from Houghton . . . I went through that business of trying to make up our own salts. And I shopped around for lower prices. But it didn't pay. ● We both know that although salt baths are an A-1 method of heat treatment, it takes experience to get the best results. ● So now I've come to rely on Houghton. They've had the experience, they treat me right, and their men have pulled us out of trouble many times, so I'm going along with them. You'll be playing safe if you do, too."

"Thanks, George, for the suggestion . . . We've bought a number of metal-working products from Houghton, and I know what you refer to, from the experience angle. I'd better put our salt bath problem up to them."—That's a sound decision; the many metal men who have made it were mighty glad they did. For salts and service you can rely on

E. F. HOUGHTON & CO.—Philadelphia 33, Pa. and all principal cities.





An example of Salmonella Typhosa Bacteria, magnified 30,000X by Electron Microscope.

Are Bacteria Biting Into Your Profits?

When bacteria and mold attack lubricants and coolants, causing them to go sour, they result in expensive production delays and costly material wastes.

Now you can prevent these microorganisms from producing *machine down time* and wasted materials. Dowicides, Dow's industrial germicides and fungicides, incorporated in cutting, grinding, rolling and hydraulic soluble oil emulsions, will prevent the growth of bacteria and mold, thus increasing the service life of the oils. Dowicides are available in both oil and water soluble types.

Keep bacteria from biting into your profits. Learn more about Dowicides today. Complete laboratory facilities are maintained by Dow to help solve your problems. Contact your nearest sales office or write direct.

THE DOW CHEMICAL COMPANY · MIDLAND, MICHIGAN

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use the

Dowicides

Industrial Germicides and Fungicides

DOW
CHEMICALS

A LITTLE ROUTINE SERVICE SAVED A LOT OF BRAZING ALLOY

In this oil burner nozzle lead, EASY-FLO 45 joins a steel tube and a copper tube to the brass forging at left. Steel tube is inside the copper tube. Both joints are induction brazed simultaneously, two assemblies at a time in 38 seconds.

It has always been our aim to help *every* user of our EASY-FLO and SIL-FOS alloys get the fullest benefit of the speed and low cost these low-temperature silver brazing alloys bring to metal joining. So, follow up is routine—and very often our men are able to come up with constructive suggestions.

For example—a user was brazing a small steel tube and a larger copper tube to a brass forging to make the oil burner part shown. He was using two rings of 1/16″ EASY-FLO 45 wire, one for each joint—and he was perfectly happy with results.

Looking in on the job our man felt that more alloy was being used than was needed. So he got some of the parts and sent them back to our research lab. There it was found that rings of 1/32″ and 3/64″ wire for the steel and copper tubes respectively, were ample. Naturally, the change was made—and the saving in cost from this little reduction in the size of alloy wire has mounted to sizable proportions.

CAN YOUR BRAZING COSTS BE CUT?

Whether or not you are now using EASY-FLO and SIL-FOS alloys, we'll be glad to send a field engineer to give you the answer—without obligating you in any way. Just write or call and say when.

For the facts about these alloys in print, write today for Bulletins 12-A and 15.

HANDY & HARMAN

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Bridgeport, Conn. • Chicago, Ill. • Los Angeles, Cal. • Providence, R. I. • Toronto, Canada

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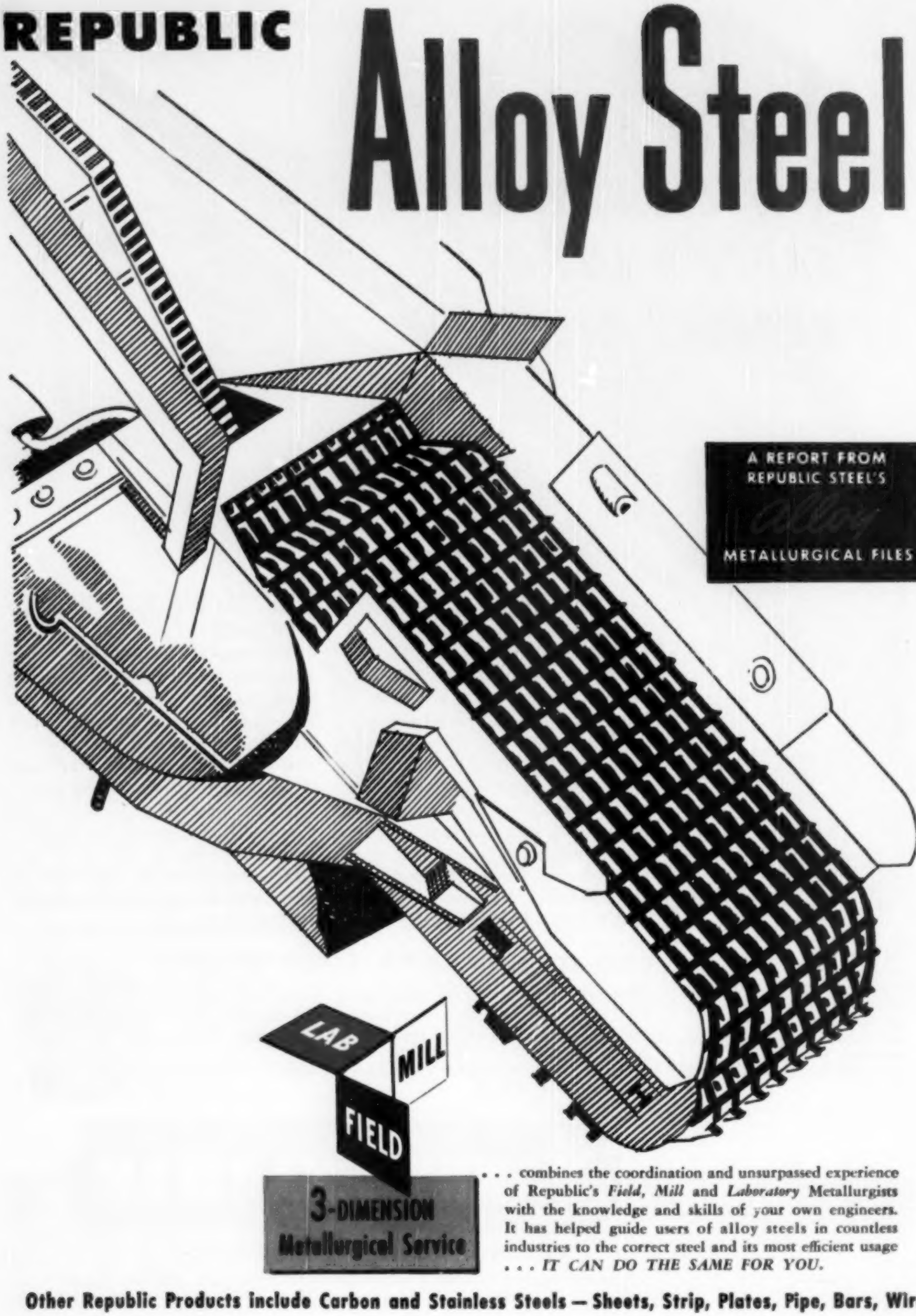

REPUBLIC
Alloy Steel
A REPORT FROM
REPUBLIC STEEL'S
alloy
METALLURGICAL FILES
LAB
MILL
FIELD
3-DIMENSION
Metallurgical Service
. . . combines the coordination and unsurpassed experience of Republic's Field, Mill and Laboratory Metallurgists with the knowledge and skills of your own engineers. It has helped guide users of alloy steels in countless industries to the correct steel and its most efficient usage . . . IT CAN DO THE SAME FOR YOU.
Other Republic Products include Carbon and Stainless Steels — Sheets, Strip, Plates, Pipe, Bars, Wire,

ENGINEERING DIGEST OF NEW PRODUCTS

DEEP DRAWING COMPOUND: A drawing compound said to maintain inherent physical properties during repeated forcible stamping of ferrous and non-ferrous alloys is announced by Northwest Chemical Co. Known as Fluid-Film, it has high film

strength and does not separate even under intense stresses. The electrical properties of the molecules at the interface, between the lubricant and the metal surfaces, remain constant during the drawing operation because of the chemical and physical stability of this compound. It is unaffected by atmosphere, its complex organic molecules resisting chemical and physical deterioration. Neutral in pH, it leaves no heavy residue nor does it leave any stain on the surface of any alloy. Photo shows a ten thousandth piece of a single operation stamping where Fluid-Film was employed.

For further information circle No. 598 on literature request card on p. 152B

THERMOCOUPLE: Molten metal thermocouple for ferrous metals has been developed by Wheelco Instruments Company. New thermocouple is designed to withstand melting temperatures up to 3200° F. and all casting temperatures normally encountered in the production of precision steel castings. Temperature readings can be made in less than 30 seconds with extreme accuracy. Thermocouple is a well balanced immersion-type sensing unit for use with any pyrometer. It has an adjustable extension and uses a 27-gauge platinum-platinum 10% rhodium element. A "telescoping" feature permits the feeding of the platinum element to the proper length within the protecting tube, without the need for cumbersome reassembling of the unit.

For further information circle No. 599 on literature request card on p. 152B

LEBANON CASTS TIMKEN ALLOY: Lebanon Steel Foundry has effected licensing agreements with The Timken Roller Bearing Company to produce and sell a patented heat-resistant super-alloy known by the trademark "16-25-6", both patent and trademark registrations being owned by the Timken company.

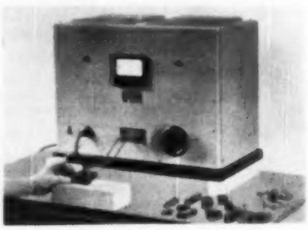
Adaptation of the material to steel casting processes is under way to broaden the company's field of operations in the production of jet engine components and other heat-resistant steel castings of aircraft quality.

Originally developed as a wrought material, the "16-25-6" alloy has demonstrated excellent mechanical properties for exacting services such as are required for rotor wheels for turbo-superchargers, jet engine and gas turbine applications, it is said. It has high creep resistance and rupture strength at elevated temperatures running as high as 1200 to 1500° F., and provides satisfactory resistance to corrosion and oxidation for the above applications at similarly high operating temperatures.

For further information circle No. 600 on literature request card on p. 152B

PORTABLE INDUCTION UNIT: New low-cost, high-frequency induction heating unit has been introduced by Lepel High Frequency Laboratories, Inc., to fit the requirements of machine shops, toolrooms, research laboratories and educational institutions.

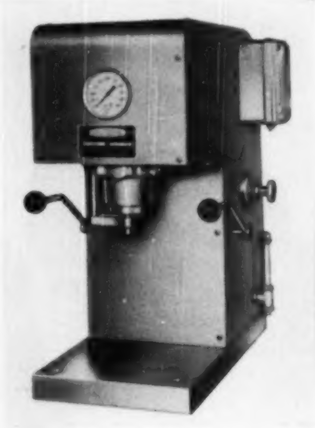
Moderately priced at $780, unit is said to heat one-inch length of steel



rod to 1500 degrees F. in approximately 3 seconds. Will braze carbide tips to cutting tools up to 1⅛ in. square, melt four ounces of steel or brass in four minutes. Heating unit is shown brazing carbide tips to cutting tools.

For further information circle No. 601 on literature request card on p. 152B

HYDRAULIC PRESS: To its line of air-operated "Han-D-Presses", Hannifin Corp. is adding a hydraulic "Han-D-Press", available as the F-10 (1-Ton) or as the F-20 (2-Ton). Developed to meet the need for a fast-acting, precision unit to help speed



up light, but often troublesome, production operations, such as staking, marking, broaching, punching, riveting and press-assembly, the new hydraulic is completely self-contained and can be used where compressed air is not available.

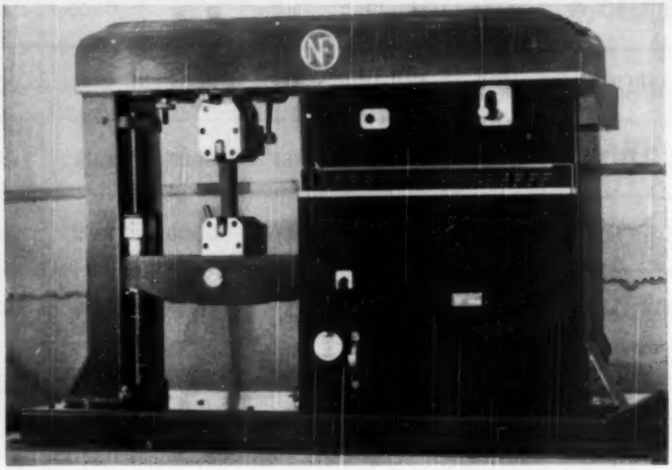
For further information circle No. 602 on literature request card on p. 152B

ALUMINUM GEARS: A new gear made of aluminum, with a bonded-in steel hub, has been developed by the Al-Fin Division of the Fairchild Engine and Airplane Corp. Lighter, and stronger than molded resin and fiber gears, the Al-Fin bonded gear can stand heavier loads. Gears, which are hobbed and shaved, are as quiet in operation as the composition type. Made of aluminum alloy, bonded to steel with a molecular process originally developed by Al-Fin, the gears have a tensile strength of about 15,000 psi. With steel hubs there is no danger of the aluminum gear conforming to the shaft. The gear has withstood shear tests of the bond up to 98,000 pounds.

Aluminum alloys are used for strength and heat treatment of the casting and develop a Brinell hardness of 85 to 120, depending upon requirements.

For further information circle No. 603 on literature request card on p. 152B

ENGINEERING DIGEST OF NEW PRODUCTS



TESTING MACHINE: A newly developed, simplified table model universal testing machine for tension, compression, flexure, shear, and transverse tests is available at moderate cost in two capacities: 30,000 and 15,000 pounds. The 30,000-pound capacity model has additional ranges of 6,000 pounds and 600 pounds; the 15,000-pound capacity model may be used for 3,000-pound or 300-pound testing.

The unit is compact: 42 in. high, 64 in. wide, and weighs 1,200 pounds. It is manufactured by the Testing Machine Division of National Forge and Ordnance Co.

For further information circle No. 604 on literature request card on p. 152B

ATOMAGNET: A new and improved group of nonelectric Alnico plate magnets for separation of tramp iron from materials in process is announced by Eriez Manufacturing Co. Known as ATOMAGNETS, they come in three models, each with a different magnetic strength: the "Extrapower", the "Ultrapower", and the "Superpower". Each also comes in a full range of sizes.

Five new features of ATOMAGNETS make them the most advanced permanent magnet separators available, according to the company.

1. The magnet castings are now fully encased with a formed cover. This increases longitudinal stiffness; prevents tampering and accumulation of iron on the backs of castings with consequent formation of auxiliary magnetic poles that detract from the efficiency of the normal magnetic field.

2. Parts are riveted rather than bolted together for added structural strength. Warping and bending of large size magnets is eliminated.

3. The hinges on standard models are now made of aluminum, continuous and offset. They have greater strength than earlier types, fit in many positions without the use of spacers, and are of course nonmagnetic so that they exercise no effect on the efficiency of the magnet.

4. Insulation of the plate's working surface confines magnetic strength to where it is desired. There is no bleeding of magnetism to surrounding areas with consequent loss of pulling power soon after installation.

5. A flush instead of recessed air gap on the plate face prevents gathering of fine iron in this crucial location. If allowed to collect here, the iron can short out the magnetic field.

For further information circle No. 605 on literature request card on p. 152B

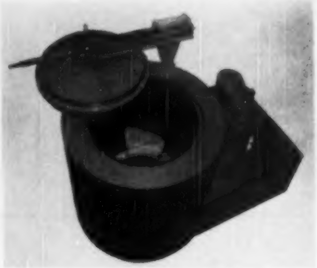
MASONRY SAW PUMP: A new type pump, for use on wet cutting saws, has been announced by Champion Manufacturing Co. Designated as the Model "C", pump carries a one-year guarantee. Small and compact, the new pump does away with the extra belt and pulley formerly used. It can be run dry without harm, should the wet cutting models be used for dry cutting.

For further information circle No. 606 on literature request card on p. 152B

ENGINEERING DIGEST OF NEW PRODUCTS

VERTICAL FURNACE: "Radivection" denotes a heat treating apparatus (Patent Pending) of the recirculating type said to offer improved temperature uniformity, during both the heating and heated stage of a treatment, through all parts of the work load by means of equated heat distribution. Equated heat distribution is the employment of two pass, or folded convection, combined with a variable volume and velocity of the convection heat carrier gases introduced around and outside of the side walls of the work basket at the bottom only. The heat carrier gases are forced around and generally toward the opposite end (or top) still outside of the work basket. The gases move in a flat spiral motion giving up part of their heat to the load by radiation and conduction through the walls of the basket.

As the gases, at reduced temperature (lower heat content), reach the opposite end of the work basket outer area, they move inward to the load proper. Here, the flow direction is reversed moving toward the end of initial entry, inside the work chamber, releasing further heat to the work by direct contact. The gases then pass from the work chamber through a recirculating blower and into a reheating area.



These features of "Radivection" are combined to offer heat transfer apparatus for temperatures from 250 to 1850° F. "Radivection" not only offers uniformity during heating and heated stages of a treatment cycle, but its reduced maintenance, lower operating cost, standardized parts replacement and simplified operation are strong points in its favor. It is available in all sizes, vertical or horizontal loading, and most methods of heating including gas, oil and electric. The Standard American Engineering Co.

For further information circle No. 607 on literature request card on p. 152B

DYNAMIC STRAIN AMPLIFIER: A new type, portable strain amplifier, designed for use with any standard cathode ray oscilloscope to measure almost any mechanical reaction detected by SR-4 bonded resistance wire strain gages, is announced by The Baldwin Locomotive Works, Philadelphia 42, Pa.

This instrument, known as the Model BA-1, may be used for load measurements, stress analysis and function analysis during operation of equipment to show amplitude, frequency and wave form of sharp transients, steady state oscillations, static loads or their combinations. Displacement, acceleration, vibration, damping, timing, weight, and pressure can be seen and measured during operation of machines or mechanical devices. Data may be recorded by means of either special high speed cameras or an ordinary still camera without shutter.

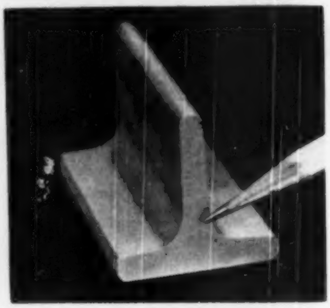
The BA-1 is a complete package of bridge elements, signal chopper, calibration system, amplifier and power supply. The signal chopper is a unique feature which indicates the static unbalance of the bridge. Static and low-frequency components of the signal are shown with the signal chopper on and high frequencies are observed with the chopper off. The amplifier reproduces all frequencies between flat 5 to 20,000 cps. Noise level is minimized by use of battery power, shock mounting and proper selection of components.

Micro-inches in strain can be determined by using graphed curves in the cover of the instrument. This is a calibration means for predetermining the amount of deflection in the oscilloscope beam from zero to several thousand micro-inches strain. This is advantageous in dynamic work because the speed of the trace deflection is too fast to read and interpret as it occurs.

The instrument is contained in a case approximately 12 x 10 x 8 in. and weighs 22 lbs. with batteries.

For further information circle No. 608 on literature request card on p. 152B

INCONEL "T" SECTIONS: Availability of hot rolled Inconel in equal "T" sections has been announced by The International Nickel Company, Inc. "T" sections are made in a standard size 1½ by 1⅛ by ¼ inches,



and in lengths up to 15 feet. The weight is approximately 2¾ pounds a foot.

The primary purpose of the new product is to provide manufacturers of furnaces and other high temperature equipment with ready-made and uniform structural parts at considerable economy over the cost of fabricating those parts in their own shops. The section can be welded, riveted, or otherwise joined without difficulty.

For further information circle No. 609 on literature request card on p. 152B

RESEARCH MICROSCOPES: A new series of research microscopes and accessories, that permit exhaustive study of a wide variety of specimens, have been developed by Bausch & Lomb Optical Co.

Known as the Series "E", all models have an inclined binocular body that can be interchanged with a graduated monocular draw tube for photomicrography, measuring, microprojection and other research applications. The draw tube is adjustable and graduated from 146 to 172 mm. in tube length.

Three types of substages are also provided for routine, specialized and most critical research.

Other features include a deeply curved arm that allows ample clearance for various specimens and full rotation of the microscope stage, coated optical elements that afford maximum light transmission, and a low position, fine focusing adjustment that is only 70 mm. above the table level.

For further information circle No. 610 on literature request card on p. 152B

NEW STAINLESS STEEL: Armco Steel Corp. has announced the development of a new stainless steel for television viewing tubes. New alloy, Armco 430 ELC Stainless Steel was developed specifically for metal-glass picture tubes after more than a year of intensive research.

With the trend to larger television screens and more recently to the rectangular tube, television manufacturers have become more interested in the metal-glass tube. A drawback, however, has been the cost of the special stainless steel required for the metal tube section.

In order to get continuous thermal contraction of about the same rate as glass during cooling, it was formerly necessary to use either 28% chromium steel or 17% chromium steel with special stabilizing elements. These ferritic alloys can be sealed to glass successfully because they undergo no phase change on cooling after the glass sealing operation. Most ordinary steels change their metallurgical structure at some point during their cooling, which results in a change in rate of contraction that can break the glass-to-metal seal.

Armco has been able to produce a low cost ferritic stainless steel without the use of expensive stabilizing elements by reducing the carbon content to below 0.03%. Type 430 ELC is made by the same process as is used to produce Armco's other extra low carbon grades of chromium-nickel stainless steel, Types 304 ELC, 316 ELC, and 317 ELC.

For further information circle No. 611 on literature request card on p. 152B

PREPO TORCH: Air Reduction Sales Company has been appointed national distributor for the welding industry of the recently introduced Prepo Torch.

This torch is said to give an instant heat at 2200° F. and permits immediate application of a hot flame for soldering joints, loosening nuts, sweating cable and many other operations. No preheating, pumping or priming is required.

The lightweight (1½ pounds) torch may be used in any position and features a throw-away fuel container. Under ordinary use, one container will last for over four hours, depending on the size of burner.

For further information circle No. 612 on literature request card on p. 152B

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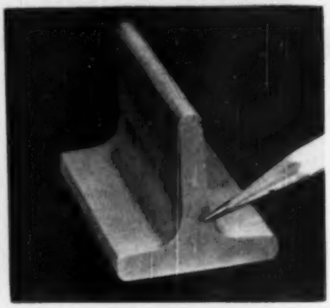

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For further information circle No. 612 on literature request card on p. 152B

613. Alloys, Fabricated
New catalog is available, showing cost-cutting fabricated heat treating equipment for higher pay loads and better quality. *Rolock, Inc.*

614. Alloys, Low-Melting
Bulletin J4-6-49 outlines characteristics of Cerro alloys and lists physical properties as well as many and varied applications of these bismuth alloys that melt at low temperatures (117° to 440°F) for the various compositions. *Cerro dePasco Copper Corp.*

615. Alloys, Nickel
New technical bulletin T-6 discusses resistance of nickel and its alloys to corrosion by caustic alkalies. *International Nickel Co.*

616. Alloys, Nickel
Hastelloy nickel-base alloys are available for fabricating corrosion-resistant screen, cloth and baskets. Also for metal spraying many types of automatic welding and hardfacing. Booklet, "Hastelloy High-Strength Nickel-Base Corrosion-Resistant Alloys", gives full details. *Haynes Stellite Co.*

617. Alloys, Nickel
Technical bulletin, "Cast 16% Cr – 35% Ni Alloys", completely illustrates heat, corrosion and abrasive-resistant cast alloys. *Electro Alloys Div.*

618. Aluminum Tubes and Shapes
New price list available on aluminum tubes and extruded aluminum shapes, rods and bars. *Revere Copper and Brass, Inc.*

619. Belts, Metal
Bulletin 47P illustrates and describes complete line of wire belts for industry. *Ashworth Brothers, Inc.*

620. Beryllium-Copper
New technical bulletin No. 1 gives case history and technical information on Berylco 165 strip. First in a series of data sheets to provide the engineer with facts on beryllium copper. *The Beryllium Corp.*

621. Blackening Process
New bulletin illustrating and describing the Ebonol blackening process for steel, copper, brass, zinc parts. *Enthone, Inc.*

622. Brazing Alloys
Easy-Flo and Sil-Fos alloys provide a simple, versatile method of fabricating nonferrous and dissimilar metals, as described in bulletins 12-A and 15. *Handy & Harman.*

623. Castings
Bulletin FC-350 outlines the many advantages of improved Fahrite corrosion-resistant castings. *Ohio Steel Foundry Co.*

624. Castings, Iron
"Abrasion-Resistant High-Chromium Iron" is a booklet containing the best available information on how to make and use abrasion-resistant iron castings. *Electro Metallurgical Div.*

625. Chrome Plating
New bulletin describes homogeneous lead anodes for chrome plating, with the exclusive feature of a copper hook homogeneously bonded to the lead, assuring positive electrical contact for entire life of anode. *Republic Lead Equipment Co.*

626. Cleaning, Electrolytic
New booklet, "An Introduction to Electrolytic Cleaning", contains general information on this process and explains simply the phenomena taking place during both direct and reverse current cleaning, and the advantages of each. *DuBois Co.*

627. Controller
Write for Specification Sheet 112 illustrating new Pyr-O-Vane millivoltmeter controller. It is electronically controlled, plugs in and is immune to ambient temperature changes. Also features fail-safe design and thermocouple burnout for protection of work load. *Brown Instrument Co.*

628. Control Valves
Catalog 100, section 4, gives complete data on Logan air control valves for every type of operation. Various installations are clearly outlined in photographic blueprints of each line connection. *Logansport Machine Co.*

629. Disc Grinding
A new booklet on "Disc Grinding" discusses safe handling, storage, mounting, and use of abrasive discs and describes main features of this type of precision grinding. *Grinding Wheel Institute.*

630. Drawing Dies
Attractive 4-page catalog detailing specifications for standard wire, bar and tube drawing dies in a convenient three-ring binder, and including the recently agreed on new size die nibs and standard casing sizes. *Adamas Carbide Corp.*

631. Electrodes, Welding
New catalog presents complete line of shielded-arc electrodes for welding of mild steels and alloy steels; gives complete specifications, operating characteristics, mechanical properties, and applications. *McKay Co.*

632. Electropolishing
Attractive photo-illustrated 14-page booklet gives complete story of American electropolishing, including composition, equipment, and various applications of this valuable process for bright polishing of both nickel-chrome and plain chrome steels. *American Steel and Wire Co.*

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

633. Fastener
New bulletin lists 69 stock sizes of the Speed Grip Nut Retainer. Tried by manufacturers for 18 months, these have proven the most popular sizes. Complete specifications listed. *Tinnerman Products Co.*

634. Finishing
Alodine aluminum bonds paint to aluminum and protects the metal economically, with no plating equipment required. Applied with dip, spray, brush and flow coat, it provides a simple, easy process for lasting, corrosion-resistant finish. *American Chemical Paint Co.*

635. Fittings, Stainless Steel
New stainless steel welding fittings price list (52W) contains latest prices covering a variety of fittings such as elbows, return bends, stub ends, tees, etc., in Types 304, 316 and 347 stainless steel. *Cooper Alloy Foundry Co.*

636. Forging
Bulletin 91-A describes new wide adjustment forging rolls available in six sizes for pre-rolling blanks from smallest to largest in fast, accurate, metal-saving operation. *Ajax Mfg. Co.*

637. Furnace
New brochure describes batch-type controlled atmosphere furnace in actual plant operation, including charts showing uniformity of gas-cyanided case depths obtained and typical operating cost breakdowns for light case parts. *Dow Furnace Co.*

638. Furnace
Bulletin SC-147 describes new rotary retort-controlled atmosphere furnace for fully automatic high production heat treatments including gas carburizing, dry cyaniding, homogeneous carburizing and cleaning hardening. Also equipped with internal screw-thread for smooth, even heating of small metal parts. *Surface Combustion Corp.*

639. Furnaces
New catalog on Heroult gantry-type electric melting furnace with patented roof-ring to assure speedy and simple bricking and elimination of skew shapes. *American Bridge Co.*

640. Furnaces
Bulletin T-1420 illustrates and describes Lindberg LI-25 induction heating unit. A ruggedly constructed vacuum-tube type of unit for hard working production-line jobs. Ideal for hardening, brazing and soldering, annealing and stress relieving, hot forming and light forging, shrink fitting and other induction heating applications. *Lindberg Engineering Co.*

641. Furnaces
Bulletin 411R describes the Rockwell reverberatory melting furnace, a portable oil-fired furnace installation that melts 10,000 lbs. of aluminum per charge. Also in tilting types. *W. S. Rockwell Co.*

642. Furnaces, Annealing
Vertical strip annealing furnaces improve silicon steel production and provide excellent surface characteristics which increase stamping die life. *Drever Co.*

643. Furnaces, Hardening
Catalog A18 tells the story of the H.S.S. Hardening Furnaces for versatile, economical heat treating to save on hardening costs and increase tool production. *Sentry Co.*

644. Gas-Analysis Equipment
New "Gas-Analysis Manual" contains authoritative technical information on gas analysis with a description of all units, including those with the new ball-and-socket connectors, and a complete, current price list. *Fisher Scientific Co.*

645. Gears
Information on all types of gearing specifications including Neloy, spur, bevel, mitre, Sykes Herringbone, available in bulletin No. 9, sent on request. *National Erie Corp.*

646. Grinding and Polishing
New booklet entitled "Why Thousands of Shops Have Switched" describes advantages of backstand grinding and polishing metalite cloth belts. *Behr-Manning Corp.*

647. Grinding Wheels
4-page bulletin ESA-191 illustrates grinding wheels for plain cylindrical grinding and includes grain and grade recommendations in addition to popular wheel sizes and data on speeds and feeds. *Simonds Abrasive Co.*

648. Hardness Testers
Bulletin DH-114 contains full information on Tukon hardness testers for use in research and industrial testing of metallic and nonmetallic materials. Also included is bulletin DH-7, giving experiences in various fields. *Wilson Mechanical Instrument Co.*

649. Heat Treating
Pressed steel lightweight sheet alloy heat treating units furnished in any size, design or specification. Write for full information on this. *The Pressed Steel Co.*

650. Heat Treating
Bulletin HD-1147 gives complete details on the low-cost, high-quality heat treating unit composed of a "Tempyrite" tempering furnace, "Treet-All" multi-purpose furnace, "Alloy 10" high temperature furnace, and "Atmo-Gen" atmosphere generator and control accessories. *Hevi Duty Electric Co.*

651. Heat Treating
Bulletin 123 describes how production is doubled, surface protection improved, and life of tools increased through the use of Ajax salt bath heat treating equipment. *Ajax Electric Co.*

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

652. High-Temperature Testing
For precise hi-temperature testing, send for illustrated technical folder on Marshall equipment. *L. H. Marshall Co.*

653. Immersion Heating
Bulletin IE-11 gives complete details on how new immersion pots save time and money in melting soft metals. High thermal efficiency for both large and small units provides rapid heat recovery in one-third the time. *C. M. Kemp Mfg. Co.*

654. Industrial Planning
New book 127 tells how you can share in a "round-table" discussion of planning expansion, remodeling or modernization of your plant. *Continental Industrial Engineers, Inc.*

655. Infrared Recorders
Bulletin 33 entitled "Infrared Recording Spectrophotometer" describes unique construction and operation of these instruments for use in production and testing of organic compounds. Two types of infrared spectrometers, the single-beam and double-beam, provide maximum speed and accuracy in qualitative and quantitative analysis of specimens. *Baird Associates, Inc.*

656. Insulating Compound
New vinyl insulating compound, especially designed for high temperature service, protects iron constantan and copper constantan thermocouple lead wires. Write for further information. *B. F. Goodrich Chemical Co.*

657. Lubricants
Interesting facts on how shop operation can be more efficient and economical through the use of right lubricants described in "Metal Cutting Fluids". *Cities Service Oil Co.*

658. Lubrication of Hot Metals
New bulletin 426 describes how (DAG) colloidal graphite can solve your lubrication problems in hot metal forming operations. *Acheson Colloids Corp.*

659. Melting, Induction
8-page illustrated article describes use of induction melting in improved technique for rotor-casting. *Ajax Engineering Corp.*

660. Metal Identification
Chart entitled "Simple Tests for Identifying Metals — To Aid in the Determination of Correct Oxy-Acetylene Welding Procedure" furnishes an easy method for distinguishing 13 different metals and alloys. *International Acetylene Assn.*

661. Metal Plates
For full information on solid or clad plates in the exact grade you need to combat corrosion, oxidation and contamination, write for new A-L Plate Book. *Allegheny Ludlum Steel Corp.*

662. Metalworking Data File
Fingertip reference file 503 contains engineering information about equipment and processes used for metal stampings, heavy weldments and pressed steel shapes. *Chas. T. Brandt, Inc.*

663. Microscopes
Catalog D-1010 illustrates and describes new E series of microscopes for the most exacting research work. *Bausch & Lomb Optical Co.*

664. Oil Burner
New catalog No. 456 describes the Venturi high pressure steam or air atomizing oil burner for industrial firing applications in smelting, oil refining, and metal heat treating of various types. *Hauck Mfg. Co.*

665. Paint Primer
"Protecting Gas Holders" is the title of the latest in a series of booklets outlining the advantages of silica graphite paint in reducing yearly maintenance costs of gas holders. Also provides valuable data on protection of metal structures of all types. *Joseph Dixon Crucible Co.*

666. Parts, Baskets
Baskets designed for your individual needs in handling parts. All types of trays, fixtures, retorts, and carburizing boxes are described in catalog 16. *Stanwood Corp.*

667. Photomicrographic Camera
New folder furnishes a full description of the Gamma "U" camera and its complete line of accessories for micro, low power, macro and copying work. *Gamma Instrument Co.*

668. Polishing and Buffing
Bulletin entitled "Acme Straightline Automatic Polishing and Buffing Machines" illustrates and describes a machine for every type of production polishing and buffing job. *Acme Mfg. Co.*

669. Potentiometer, Portable
Bulletins 270 and 270-A describe portable potentiometers in a selection of ranges up to 1.6 volts. *Rubicon Co.*

670. Potentiometers
Dynalog instruments for control of temperature, humidity, pressure, flow, etc. Details in bulletin 427. *Foxboro Co.*

671. Pyrometer
Catalog No. 80 illustrates and describes the Pyro Optical Pyrometer for quick, accurate temperature readings on minute spots, fast-moving objects and small streams in a temperature range from 1400°F to 7500°F. *The Pyrometer Instrument Co.*

672. Pyrometers
Catalog ND44(1) gives further information on Micromax recording instruments for regulating fuel proportions, resetting equipment after loading and constantly maintaining even temperatures during entire heat treating process. *Leeds & Northrup Co.*

673. Refractories
New booklet on KX-99 refractories for the steel industry tells how these furnace bricks were developed especially with low porosity and high bulk density, for tough, hard wear in bottoms of blast furnaces. *A. P. Green Fire Brick Co.*

674. Refractories
Complete details on refractory cements for every nonferrous melting operation are available in catalog 863. *Norton Co.*

675. Refractories
Revised bulletin entitled "Lumnite Refractory Concrete" discusses latest available information on refractories and heat-resistant concrete. *Lumnite Div., Universal Atlas Cement Co.*

676. Rust Preventives
80-page color illustrated, conveniently indexed book discusses the various No-Ox-Id rust preventives for every industrial purpose. In addition, this booklet contains general information of value to anyone concerned with the prevention of corrosion. *Dearborn Chemical Co.*

677. Salt Baths
32-page bulletin entitled "Houghton Liquid Salt Baths" discusses the advantages of this process for tempering, brazing, annealing, hardening, reheating, and carburizing. Also contains many pages of factual heat treating data. *E. F. Houghton & Co.*

678. Springs
New two-color bulletin describes, by engineering drawings and application photographs, the four major forms of the neg'ator — an elastic member possessing either constant or negative force-deflection characteristics. *Hunter Spring Co.*

679. Steel, Pressed
New pamphlet now available on ACF deep drawn pressed steel, with illustrations of standard products that can be manufactured from hot-rolled or cold-rolled carbon steel or in chrome-nickel stainless steel, in a variety of finishes. *American Car & Foundry Co.*

680. Steel Mill Equipment
Attractive bulletin illustrates complete line of hydraulic presses, steel mill equipment, iron and steel rolls, grinding machines, steel castings and jaw crushers. *Birdsboro Steel Foundry & Machine Co.*

681. Temperature Testing
New bulletin 4257 describes Alnor Pyrocon, handy instrument for reading surface temperatures quickly and accurately whether they are metallic, nonmetallic, flat, curved, stationary or revolving. *Illinois Testing Labs.*

682. Tempilstiks°
"Basic Guide to Ferrous Metallurgy", a plastic laminated wall chart in color, furnished on request. *Tempil° Corp.*

683. Testing
Bulletin 2005 describes new high speed automatic "Cyclograph" equipment for nondestructive sorting and inspection of metal parts by their metallurgical characteristics. Sorting speeds of 1 to 5 parts per second can be obtained. *J. W. Dice Co.*

684. Testing Machine
Bulletin 310 describes new, low-cost Model 60-H universal testing machine with 60,000-lb. capacity, constructed in the convenient two-unit design which allows varying of positions to suit any space requirement. *Baldwin Locomotive Works.*

685. Thermocouples
Catalog 59-R tells complete story about use of Chromel-Alumel couples and extension leads. *Hoskins Mfg. Co.*

686. Thermocouples
A new 34-page catalog, Reference H, will furnish complete data on thermocouples, quick-coupling connectors, thermocouple wire, lead wire, protection tubes, etc. *Thermo Electric Co.*

687. Tin Plating
New technical bulletin on electro-tinning contains 24 pages on bath formulae and performance data for both potassium and sodium stannate plating solutions, and also a section on the new high speed tin anodes. *Metal & Thermit Corp.*

688. Tool Steels
For full information on better, lower-cost tooling, send for practical, easy-to-use 189-page Carpenter Matched Tool Steel Manual. *Carpenter Steel Co.*

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METAL PROGRESS
7301 Euclid Avenue, Cleveland 3, Ohio
August, 1950

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AIRCO RESEARCH
tames the tough-to-weld metals

Air Reduction's planned research and development program has brought forth many new products and techniques for the metal working industry – the latest is the patented Aircomatic® Process.

Without a doubt, this revolutionary welding process represents one of the greatest advances in metal working history. It is a gas-shielded metal arc method of welding which permits the joining of aluminum, aluminum bronze and stainless steel – *in all positions at welding speeds higher than ever before possible.*

Continuous feeding of filler metal, and inert gas shielding, are the two main features that give this new welding method its exceptional speed and flexibility. A bare filler metal, in wire form, is fed continuously through a specially designed gun . . . and, of utmost importance, the process deposits a weld metal with an analysis almost identical to the base metal.

Further, to widen the field of Aircomatic application, Airco research is still working to achieve higher welding speeds and greater welding economies.

But, research on this high-speed welding technique is only *one* phase of Air Reduction's accelerated program. This same forward thinking is at work in the development of oxygen and acetylene processes – and products – for the entire metal industry.

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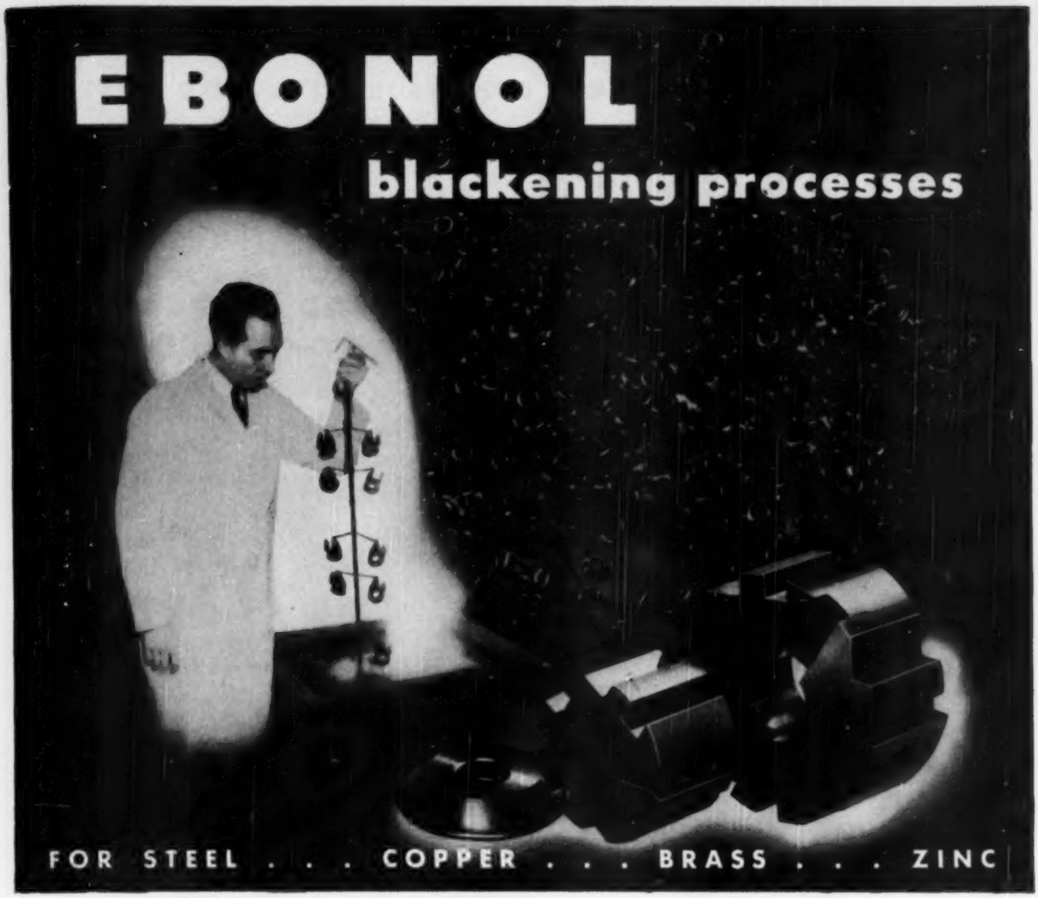

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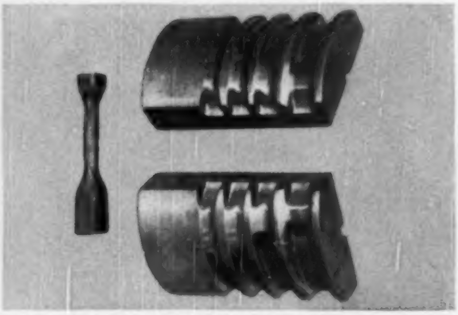

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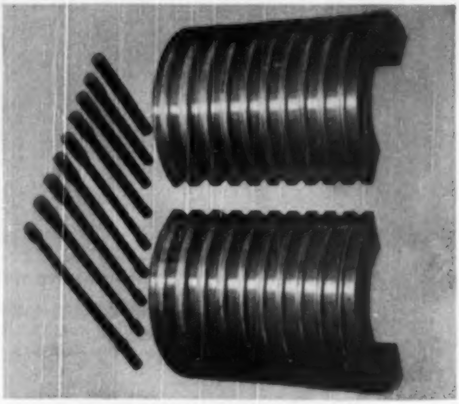
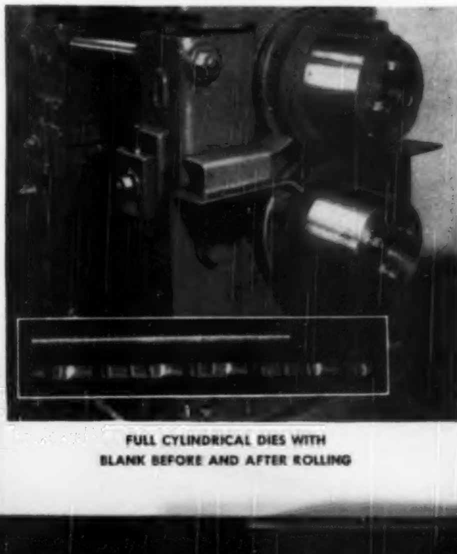
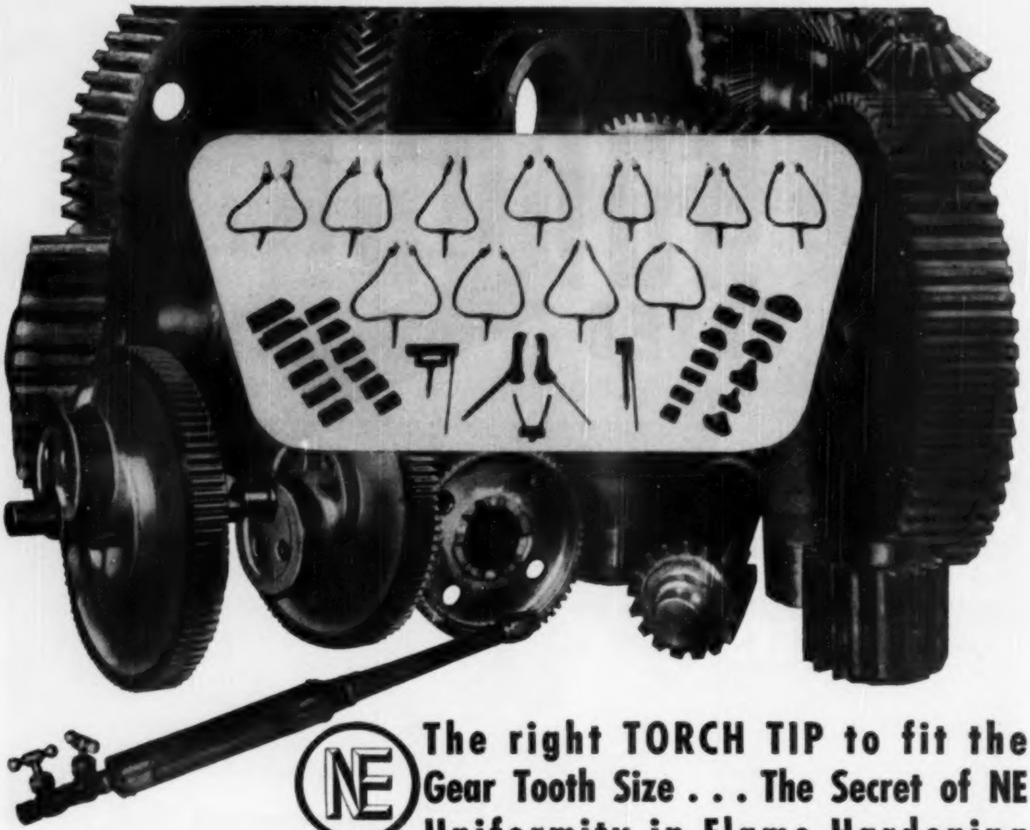


SEMI-CYLINDRICAL DIES & AXLE SHAFT



FULL CYLINDRICAL DIES WITH BLANK BEFORE AND AFTER ROLLING



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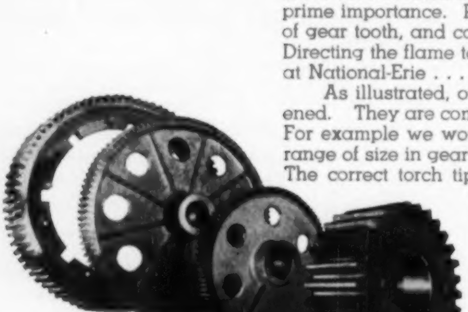

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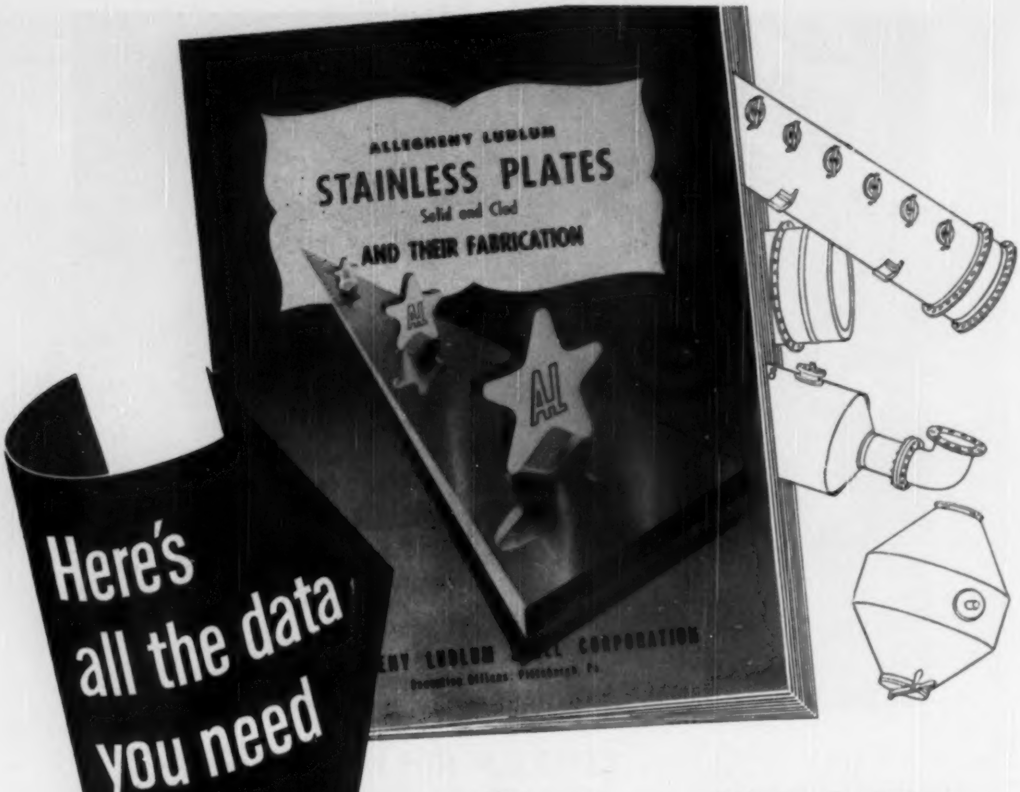

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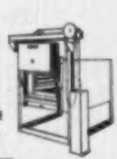

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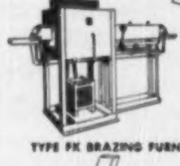

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indirect arc	alloy iron and malleable iron	lining	RA1144	coarse grain Alundum* cement	2100°F	2950°F	rammed
		patching	RA1160		1850°F		rammed
		troweling around electrodes	RA162	fine grain Alundum cement	1850°F	2950°F	troweled
direct arc	alloy steel and malleable iron	lining roof and around electrodes	RA1144	coarse grain Alundum cement	2100°F	2950°F	rammed
		lining roof and around electrodes	RA1195	very coarse grain Alundum cement	2000°F	3100°F	rammed
		patching	RA1160		1850°F		rammed
high frequency induction	stainless steel and refractory alloys	lining	RM1169	very coarse grain Magnorite* cement	2100°F	3250°F	rammed (dry)
		patching large furnaces	RM868	medium grain Magnorite cement	2200F°	2750°F	rammed
		patching small furnaces	RM1171	medium grain Magnorite cement	2000°F	2900°F	troweled or rammed

for non-ferrous metal-melting furnaces

low frequency induction	refractory alloys, cupronickel, nickel silver, high copper alloys Al, Te, Si bronzes	lining	RM1140	coarse grain Magnorite cement	2300°F	3250°F	rammed
	nickel silver	lining	RA1195	very coarse grain Alundum cement	2000°F.	3100°F	rammed
	brasses not more than 90% copper or less than 10% zinc	lining	RA1144	coarse grain Alundum cement	2100°F	2950°F	rammed
indirect arc	nickel and high nickel alloys	lining	RA1144	coarse grain Alundum cement	2100°F	2950°F	rammed
		patching	RA1160		1850°F		
crucible melting furnaces■	brasses and bronzes	lining and patching	RC1188	coarse grain Crystolon* cement	2000°F	3050°F	rammed
		lining and patching	RC1133	coarse grain Crystolon cement	2100°F	2950°F	rammed
		lining and patching	RC1204	coarse grain Crystolon cement	2000°F	2900°F	rammed
reverberatory furnaces ▼	brasses and bronzes	lining and patching	RC1188	coarse grain Crystolon cement	2000°F	3050°F	rammed
		lining and patching	RC1133	coarse grain Crystolon cement	2100°F	2950°F	rammed
		lining and patching	RC1204	coarse grain Crystolon cement	2000°F	2900°F	rammed

■ Cement not in contact with metal, used in combustion chamber.
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METAL PROGRESS

Vol. 58 *August, 1950* *No. 2*

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Many tool failures are mechanical. Those dealt with here are related to design, mechanical processing and service loads. Improper heat treatment is a major cause of tool failures, but that subject is reserved for another article by Mr. Riedel. Distortion of tools in heat treatment will be considered in a third installment.

Causes of Tool Failures

I—Mechanical Factors

THE MANUFACTURER of production tools is faced with two major problems. The first is to produce a tool that is hard enough to withstand the anticipated service conditions and, at the same time, is tough enough so that it does not crack during manufacture or use. The second problem is to produce a tool that will be of the proper size and shape after it has been hardened, without the necessity for excessive "finishing" of the hardened surfaces. By studying tools that have failed, methods of avoiding similar failures can be developed. Thus, from a knowledge of "how *not* to make tools", we learn how to make tools properly.

The types of steel under consideration in this article are the common toolsteel grades used in large quantities and produced by virtually every manufacturer of toolsteel. Table I, on the next page, shows typical compositions of these ten steels, identified by their common names.

Most failures of toolsteel that are not caused by improper heat treatment may be classified as due to: *(a)* design, *(b)* forging or rolling defects in the steel, *(c)* grinding cracks, *(d)* heat checks, *(e)* rapid wear, and *(f)* premature breakage in service.

This grouping, based on the point at which trouble is first encountered, may be inexact or even misleading. For example, failures classed as due to premature breakage in service may actually be a result of grinding cracks; or tools inadequately heat treated may fail because of rapid wear. Nevertheless, the categories listed have been found useful, and a more exact classification according to basic causes would be inconvenient whenever the true cause is unknown at the time the failure is first observed.

Failures Due to Design—Many tools that crack during heat treatment should be considered as failures of design; too often the heat treater is asked to harden tools which are impossible to quench properly. The most common design faults that cause tools to crack in heat treatment are heavy sections adjacent to light sections (Fig. 1 and 2) and unnecessarily sharp corners. Fillets should be provided wherever sharp corners are not actually needed.

Some service failures should also be attributed to design faults, of which the most common are:

1. Failure to provide fillets. In some tools, such as pneumatic chisels, even a generous fillet is considered a design fault; tapers, rather than fillets, should be used to change section size or shape (Fig. 3 and 4).
2. Failure to provide proper tool clearances.
3. Excessive concentration of load.

By J. Y. Riedel
Toolsteel Engineer
Bethlehem Steel Co.
Bethlehem, Pa.

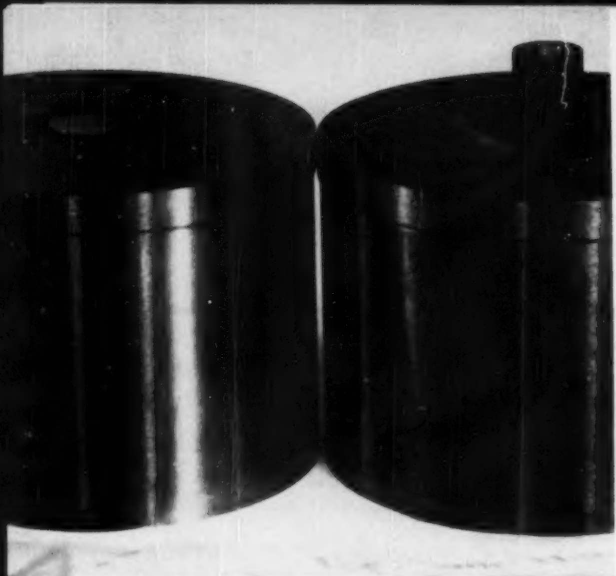

Fig. 1 — Four-Inch Diameter Rolls Made of Manganese Oil Hardening Steel. Cracked at junction of body and journal due to poor design, with heavy section adjacent to light section. These rolls should be made up as a two-piece assembly or from an air hardening steel

The design of auxiliary equipment, as well as of the tool itself, may influence the performance of the tools. For example, it is well known that the punching of holes of diameter less than the thickness of the material is difficult, if not impossible, due to punch breakage. However, if the punch is designed to work in a close-fitting supporting bushing, holes can often be punched which otherwise would have to be drilled.

A further example of the effect of design on the use of tools is in punching hard steel such as railroad tie plates. If punches for an application such as this are allowed to go all the way through the plate, they wear rapidly and break when they lose clearance. To avoid this difficulty it has been found that if the punches are adjusted so that they go only about 4/5 of the way through the plate, the "button" will pop out. Since the punch does not go through the hole, the excessive wear and consequent breakage are avoided.

The effect of tool clearance on performance is readily apparent in operations such as punching and blanking. Many punch and die sets are made up with a "standard" clearance. Since the proper clearance for punching soft steel is approximately 1/10 of the stock thickness, it is apparent that standard clearances are correct for only one stock thickness. Proper clearances result in minimum tool load and sharp, clean punchings. Improper clearances result in deformed punchings, which accompany excessive tool loads.

Failures Due to Steel Defects — In spite of the extreme care used in the manufacture and inspection of toolsteel, occasionally steel containing defects is encountered. These are usually readily recognizable as material defects, of which the most common are:

1. Voids, which may be porous areas classified as "pipe" or may be large cavities due to "bursting" in rolling or forging.
2. "Streaks", which are usually located longitudinally with respect to the original bar stock and may be due to segregation, porous areas, entrapment of nonmetallic material such as slag, or mechanical defects such as laps on the surface.

Because of the random occurrence of defects, they rarely show any relation to machined tool contours. The investigation of thousands of failed tools has shown that defects in the steel account for only a few per cent of the tool failures.

Table I — Typical Compositions of Ten Common Toolsteels

Name	C	Mn	Si	Cr	W	V	Mo
Carbon Toolsteel	1.00	0.25	—	—	—	—	—
Manganese Oil Hardening	0.90	1.20	—	0.50	0.50	0.20	—
High-Carbon High-Chromium	1.55	0.40	—	11.50	—	0.40	0.80
Air Hardening	1.00	0.60	—	5.25	—	0.30	1.10
Silicon-Manganese Shock Resisting	0.60	0.70	1.85	—	—	0.20	0.45
Tungsten Shock Resisting	0.50	0.30	0.75	1.20	2.50	0.20	—
Chromium-Molybdenum-Tungsten Hot Work	0.35	0.35	1.00	5.25	1.50	—	1.65
Tungsten Hot Work	0.35	0.30	—	3.00	9.00	0.30	—
18-4-1 High Speed	0.72	0.30	—	4.00	18.00	1.00	—
6 Molybdenum, 6 Tungsten High Speed	0.82	0.30	—	4.25	6.25	1.90	5.00

Fig. 2 — Die, 4½ x 4 x 1¼ In., Made of Manganese Oil Hardening Steel. Cracked in sharp corners through light sections between the holes. This die was redesigned with more metal between the square holes

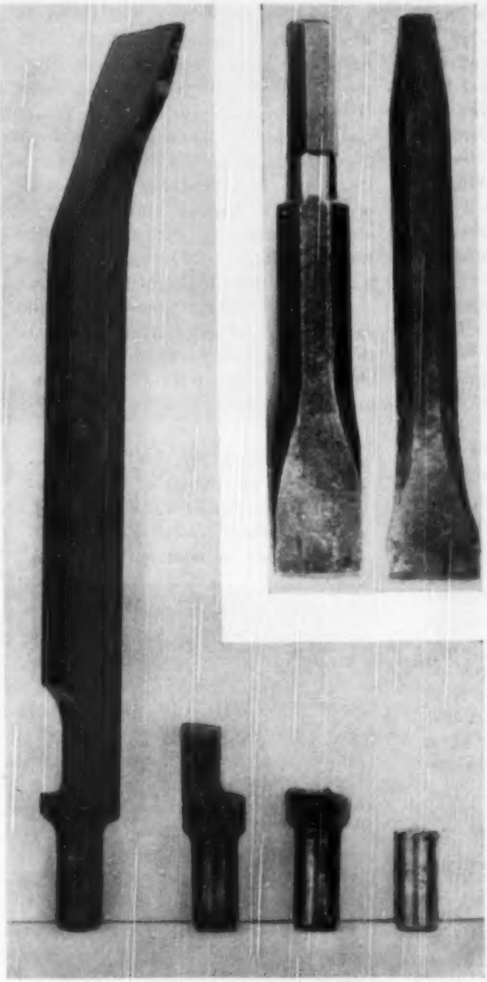

Fig. 4 — Pneumatic Chisels Showing Most Widely Used Design (left) and Improved Design (right). Even with the generous fillets shown, the chisel at left is subject to fatigue failure at the section changes. No shank failures have been observed on chisels of the improved, tapered-shank design

Fig. 3 — Pneumatic Chisels Made of Silicon-Manganese Shock Resisting Steel. Photograph shows fatigue failures at changes of section

Failures Due to Grinding Checks — The grinding of a hardened tool is usually not given much attention or thought — until trouble develops! It is obvious from the nature of the grinding operation that intense localized heating of the metal occurs under the action of the abrasive. As a result, very high surface stresses may be set up and in a highly stressed hardened tool may cause cracks (Fig. 5 and 6). Almost any properly hardened tool can be cracked by improper grinding, specifically by *(a)* scorching, which is associated with too rapid removal of metal, *(b)* grinding with a dull or loaded wheel, *(c)* grinding with a wheel of grit size too fine for the job at hand, or *(d)* ineffective use of coolant fluid.

On the other hand, if a grinder is asked to finish a tool that has not been adequately tempered, or one that has been embrittled by an excessively high quenching temperature, it is unfair to hold him responsible for cracks which develop in grinding. In instances such as this, the very best in grinding technique may not be adequate to prevent grinding cracks, and the cure must obviously be effected prior to grinding.

High-carbon high-chromium die steels are the most difficult to grind. However, if reasonable precautions are taken to use a clean, coarse-grit wheel with moderate removal of metal and adequate cooling fluid, this grade can be ground without difficulty.

Grinding checks are often so "tight" that they are almost impossible to see. They can be readily shown up by magnetic particle testing or cold etching. If they escape unnoticed and the tool is put in service, the cracks will usually enlarge, often so greatly that the tool breaks. Grinding checks often show a characteristic pattern which aids in their identification. Light grinding checks tend to occur as parallel cracks at 90° from the direction of grinding (Fig. 5), and heavy grinding

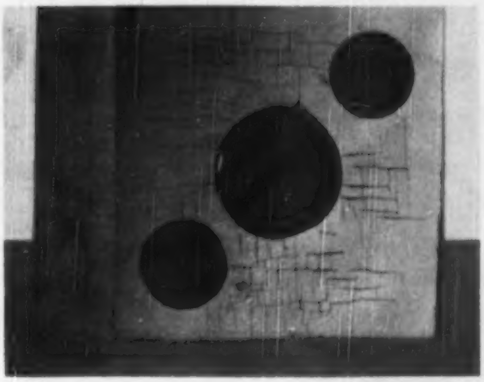

Fig. 5 — Die 3 x 2½ x 1½ In. Made of Manganese Oil Hardening Steel. Cracked in grinding

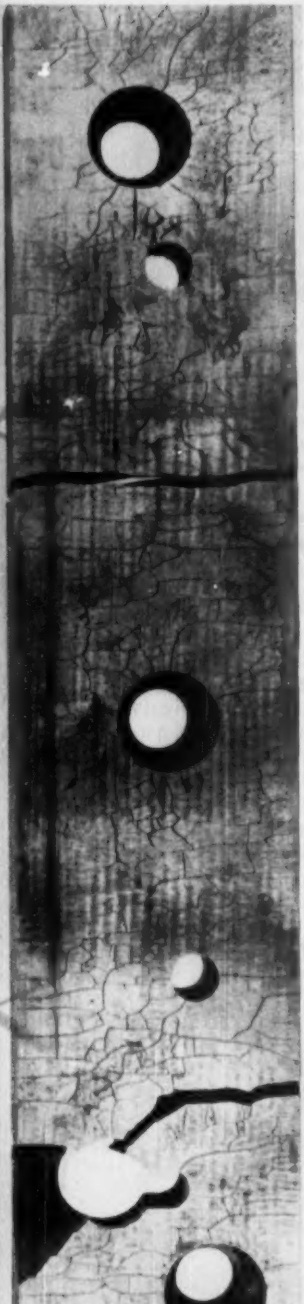

Fig. 6 — *Manganese Oil Hardening Steel Die, Severely Cracked in Grinding*

checks present a characteristic network pattern (Fig. 6).

An excellent study of the effects of grinding on hardened toolsteel has been presented by L. P. Tarasov ("Detection, Causes and Prevention of Injury in Ground Surfaces", *Transactions* A.S.M., V. 36, 1946, p. 389 to 451).

Failures Due to Heat Checks — Heat check failures of toolsteels occur largely on hot work steels. Heat checks develop as a result of repeated alternate heating and cooling. Ultimately, all steels used in hot work operations will fail by heat checking if they do not fail first in some other manner (Fig. 7).

Some hot work steels will fail rapidly by heat checking if they are water cooled between operations. Hot work steels with large amounts of tungsten and molybdenum usually fall in this category. As the tungsten and molybdenum steels have the highest red hardness, they must be used on some hot work operations. In order to avoid excessive thermal shock of the tools made of these grades, it is customary to provide duplicate tools, which are used alternately, thus allowing one tool to cool slowly while the other is in the machine. The lower-alloy hot work steels containing only small amounts of tungsten and molybdenum will usually withstand water cooling.

Occasionally tools other than those used for hot working will fail by heat checking. One instance on record involved rotary slitter knives made of high-carbon high-chromium toolsteel. Investigation of the conditions under which the slitters operated disclosed that the knives were adjusted with no clearance so that the two slitters rubbed on each other. This action resulted in the generation of enough heat to cause heat checks. Proper adjustment of the knives eliminated this trouble.

Failures Due to Rapid Wear — When tools fail by unusually rapid wear, the difficulty can often be attributed to inadequate heat treatment operations that result in either decarburized surfaces or low hardness from improper quenching. Inadequate wear resistance may also result from the use of the wrong type of toolsteel. If a blanking die is made of a 0.60% carbon shock resisting steel, it cannot be expected that the wear resistance will be as good as for a 1.50% carbon high-chromium steel.

Failures due to premature breakage are due almost entirely to one of the other types previously outlined, chiefly poor design that causes some portion of the tool to be overloaded,

Fig. 7 — *Punch Tip, 3¾ In. Diameter x 8¾ In., Made of Chromium-Molybdenum-Tungsten Hot Work Steel. Crack pattern is typical of heat checking developed on most hot work tools*

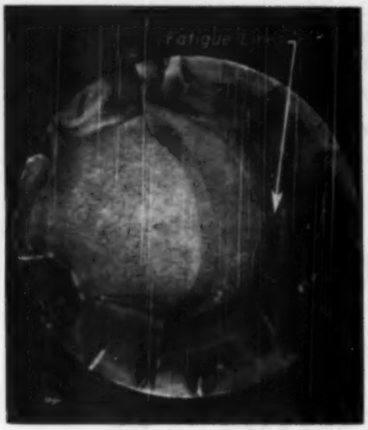

Fig. 8 — Shaft, 4¾ In. Diameter, Made of Silicon-Manganese Shock Resisting Steel. Shows characteristic fatigue failure at a change of section

or cracks resulting from improper heat treatment or grinding which were not noticed before the tool was placed in service. Premature breakage can also result from the use of the wrong toolsteel grade. For example, the use of a 1.50% carbon high-chromium steel for a chipping chisel in place of a lower-carbon shock resisting grade would lead to premature breakage.

Decarburization may also be an unsuspected source of trouble. For example, examination of some thread chasers which had shown thread breakage early in service disclosed that the tools had decarburized teeth which were not hard enough to cut properly. They deformed in service and ultimately broke out.

Premature breakage may also result from using tools at hardness levels too high for the particular job at hand. For example, most shock resisting steels are used in the hardness range between Rockwell C-55 and 60, averaging about C-58. If an attempt is made to get better wear resistance by specifying C-62, premature breakage of tools is likely.

Another type of failure which may be classed as premature breakage is fatigue. A fatigue failure is progressive: First a small crack forms; then the crack progresses part way through the section; finally the remaining section breaks suddenly due to the excessive concentration of load. Fatigue fractures always have a characteristic appearance, showing a smooth, rubbed surface where the initial crack was open and an inner crystalline zone revealed by the final sudden break. Often the rubbed surface will show parallel "oyster shell" markings (Fig. 8) and may even be rusted. Most fatigue failures are due to poor design or improper machining or finishing. They occur most often at sharp, unfilleted corners and are aggravated by tool marks or stamping. Avoidance of fatigue failures requires elimination of all stress raisers.

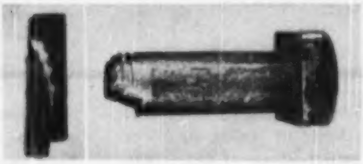

Fig. 9 — Thread Chaser Made of 18-4-1 High Speed Steel. Shows mechanical failure due to overload developed in threading an off-center bolt

Improper heat treatment can aggravate fatigue in two ways: Ineffectively quenched tools (usually with low hardness) may fail prematurely by fatigue, and decarburized surfaces which are not removed may cause premature fatigue failure.

Other Mechanical Failures — Mechanical failures of toolsteel can result from a variety of causes not yet mentioned. These include improper alignment, improper clearances, overloading by design, overloading by accident — as when two multiples go into a forming or blanking die (Fig. 9 and 10) — and overloading that may result from the use of tools with dull edges.

Fig. 10 — Nut Tap Made of 18-4-1 High Speed Steel. Failure occurred when two nuts were fed on the tap at one time

Tempering cycles of short duration are usually regarded with suspicion because of the necessity for close control. The authors show that short-time tempering by induction heating may be applied successfully to plain carbon and low-alloy steels, provided that temperature is increased to compensate for the short time.

Rapid Tempering By Induction Heating

QUENCH HARDENED STEEL is usually tempered in a furnace for an hour or more, in order to bring about thorough penetration of heat into the thickest section and to promote the maximum relief of residual stress. Tempering cycles of short duration have generally been regarded with suspicion, principally because of control difficulties.

Induction heating provides optimum conditions of heat transfer from the source of heat energy to the workpiece. While furnace or liquid bath heating is concerned with a gas-metal or a liquid-metal interface for transfer of heat, induction heating develops a high temperature within the metal itself by induced energy. Ideal conditions are thus provided for conduction of heat to the center of the piece. In conventional heating methods, moreover, the workpiece approaches the temperature of the furnace asymptotically, while in heating by induction the piece has a nearly constant heating rate to the temperature desired, thus providing maximum time at temperature in a given heating cycle.

The interrelation of tempering time and temperature in producing a given softening effect has been known in a general way for a long time. Also, it is well known that quenched steels tempered to the same hardness will have closely similar tensile properties regardless of the time cycle used in tempering. It is less certain that tempering cycles of various durations, all yielding the same hardness, are equally effective in relieving residual stress.

The purpose of this article is to study the effects of tempering cycles of a few seconds duration produced by induction heating, and to compare the results with those from conventional heating methods.

Experimental Procedure — Specimens were induction heated with a Lepel high-frequency converter at about 300,000 cycles per sec. Heating cycles were controlled and recorded by a modified high-speed recorder employing a chromel-alumel thermocouple with fine wires (0.012-in. diameter) individually percussion welded to the surface of the specimen. The controller-recorder has an electronic amplifier and a drive mechanism that enable the pen carriage to move at the rate of 1500° F. per sec. with a maximum lag of 10° F. Since, in this investigation, the heating rates did not exceed 300° F. per sec., the temperature recorded appears accurate within 10° F. The instrument controls the converter in such a way that the surface of the specimen can be held at a given temperature for any desired length of time.

Tensile tests were conducted with A.S.T.M.

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standard 0.505-in. diameter specimens of 3140 steel. These specimens were hardened by heating in a controlled-atmosphere furnace at 1550° F. and quenching in water. All specimens were heated at a rate of 300° F. per sec. and were water quenched after tempering. Stress-strain curves were recorded by a Southwark-Peters averaging extensometer. Brinell hardness values were obtained on cross sections of the specimens well removed from the fracture.

Impact tests were made on both 3140 and 1050 steel at room temperature. The specimens were 0.450-in. round, cantilever-beam test specimens (A.S.T.M. Type Y), modified to have only two notches per specimen instead of three, in order to provide a shorter specimen more easily accommodated by the heating coil. The distance between notches (1.125 in.) was not altered. The shape and depth of all notches were checked to be within the applicable A.S.T.M. specification on an optical comparator.

The specimens of 3140 steel were water quenched after heating to 1550° F. in the furnace and then cooled to −100° F. in a mixture of dry ice and alcohol to transform any retained austenite. The specimens of 1050 steel were brine quenched after heating to 1575° F. in the furnace and were then cooled to −100° F. Both steels were tempered at intervals of 100° F. from 300 to 1200° F. for 5 sec. and 60 sec. by induction, and for 1 hr. in the furnace. All specimens were water quenched after tempering to limit temper brittleness and to provide precise holding times in the short tempering cycles.

Stress relief was studied by measuring the change in the gaps of rings slit radially after induction hardening to produce definite compressive stresses in the outside layers of the ring. Gap widths were measured on an optical comparator. Three rings of 4130 steel were used, one for each tempering time of 5 sec., 60 sec., and 1 hr. The dimensions of the rings were 1¾ in. o.d. x ½ in. wide x ⅛ in. thick. The rings were hardened inductively, slit, and the deflection measured by observing reference marks on each side of the slit with the aid of the optical comparator. The rings were then tempered at intervals of 100° F. from 200 to 1300° F., using a heating rate of approximately 220° F. per sec. The 5 and 60-sec. tempering treatments were by induction and the 1-hr. tempering by furnace. Complete stress relief was obtained on all three rings by furnace tempering at 1200° F. for 2 hr. Rockwell C hardness values were obtained for each tempering cycle on similar specimens.

The effect of surface tempering was investigated by using round cantilever-beam impact specimens 1 in. in diameter and 4½ in. long, machined from 4150 steel. Two 45° notches having a depth of 0.075 in. and a bottom radius of 0.010 in. were machined in each specimen. These notches were of the same dimensions as those employed in the standard 0.450-in. round impact specimens. Eight 1-in. specimens were furnace hardened by austenitizing at 1550° F. and quenching. One group of specimens was tempered to two different hardness levels by induction heating with no holding time at temperature and another group by furnace heating for 1 hr. at temperature. In order to obtain a hardness differential between

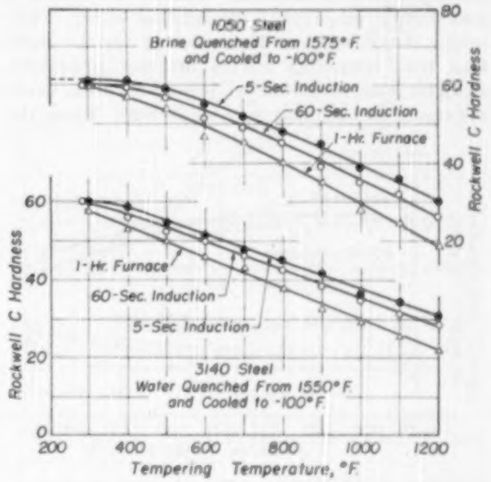

Fig. 1 — Tempering Curves for 1050 and 3140 Steels

the center and surface, the induction tempered specimens were heated at 80° F. per sec. and quenched immediately upon reaching temperature. An impact tester of 600 ft-lb. capacity was employed to break the specimens. Vickers hardness readings were taken across the diameter of each specimen after fracture to determine the hardness differential.

Effect of Tempering Time and Temperature on Hardness — Curves of hardness versus temperature and time for 1050 and 3140 steels are shown in Fig. 1 for tempering times of 5 sec., 60 sec., and 1 hr. Specimens of 5 and 60 sec. were heated by induction at a rate of 150° F. per sec.; specimens tempered for 1 hr. were heated in the furnace.

To insure that the specimens were being heated uniformly throughout, Vickers hardness readings were taken across the diameter of one specimen that had been tempered 5 sec. at 1200° F.

No variation in the hardness was found. Even a 1-in. specimen of 4150 steel which had been tempered at 1200° F. for 5 sec., using a heating rate of 80° F. per sec., showed no variation in hardness across the diameter.

In order to check the conformance of the 5-sec. tempering treatments to Hollomon and Jaffe's parameter $T(c + \log t)$, the data in Fig. 1 were applied to their formula for tempered hardness:*

$$R_C = H_C - 0.00254\,T(13.0 + \log t)$$

where H_C is the characteristic hardness or the hypothetical hardness when $T(c + \log t)$ is extrapolated to zero. Figure 2 shows the deviation of the experimental tempering curves from Hollomon and Jaffe's empirical straightline curve. The minor deviations can be explained on the basis that true tempering curves are not precisely straight lines and that in low-alloy steels some resistance to softening may be present. From the results shown in Fig. 1 and 2, it appears that the time-temperature relation $T(c + \log t)$ can be successfully extended to the hardness of steel tempered only a few seconds. Important deviations of the experimental hardness values from the calculated values occur only at tempering temperatures above 1000° F.

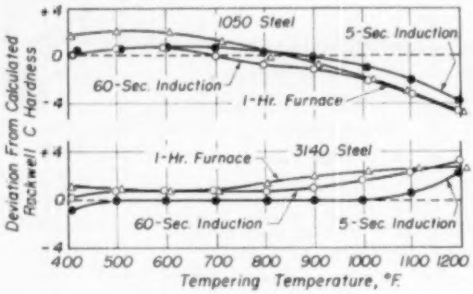

Fig. 2 — Deviation of Experimental Hardness From Hardness Calculated According to the Formula of Hollomon and Jaffe

Mechanical Properties — Since the hardness for short-time tempering cycles complies with the function $T(c + \log t)$, it is reasonable to expect that the conventional relation between Brinell hardness and mechanical properties may also exist after short-time tempering. The limitations are that the plain carbon or low-alloy steel must be quenched to a fully martensitic structure and tempered to below 200,000 psi. tensile strength.

Tensile tests were run on specimens of 3140 steel tempered 0 and 5 sec. by induction and 1 hr. in the furnace at various temperatures. In Fig. 3, the results are plotted on a reproduction of W. G. Patton's graph for the most probable mechanical properties of tempered martensite (*Metal Progress* for June 1944). Experimental points show good correlation with the most probable values found by Patton. This leads to the conclusion that the parameter $T(c + \log t)$ may be applied to other mechanical properties as well as to hardness, even for tempering cycles of only a few seconds.

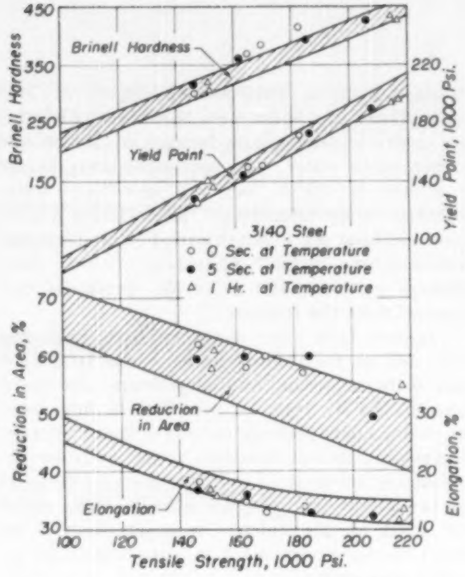

Fig. 3 — Correlation of Mechanical Properties of Tempered 3140 Steel With Most Probable Values Found by W. G. Patton

Figure 4 gives the results of room temperature impact tests on 1050 and 3140 steel. Within experimental error, room temperature impact values are a function of hardness regardless of the duration of tempering.

R. H. Greaves and J. J. A. Jones† have shown that temper brittleness is caused by a precipitating phase which has a maximum rate of reaction at about 950° F. It seemed possible that tempering cycles of 60 sec. and less might be short enough to avoid temper brittleness. The curves in Fig. 4 do not lead to a definite conclusion regarding this effect. It must be remembered that room temperature impact tests are not necessarily a satisfactory criterion for temper brittleness. Additional tests are planned to study temper brittleness by means of transition temperatures.

*"Time-Temperature Relations in Tempering Steel", by J. H. Hollomon and L. D. Jaffe, *Transactions*, A.I.M.E., Vol. 162, 1945, p. 223.

†"Temper Brittleness of Nickel-Chromium Steels", *Journal*, Iron and Steel Institute, Vol. 102, 1920, p. 171.

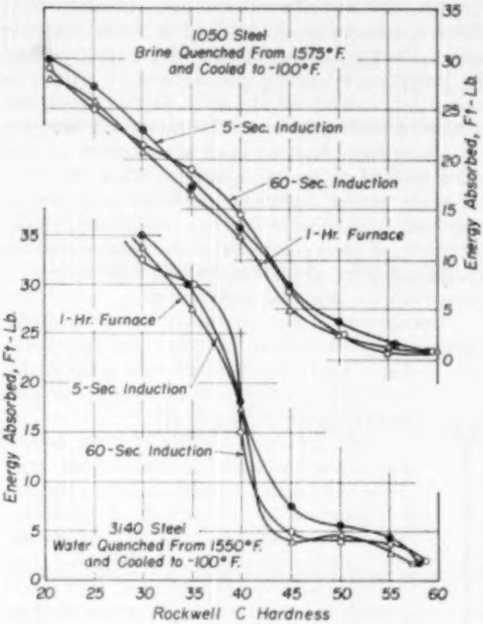

Fig. 4 — Impact Energy Versus Hardness for 1050 and 3140 Steels Tempered to Similar Hardness by Various Tempering Cycles

Relief of Residual Stresses — The satisfactory mechanical properties of 1050 and 3140 steel tempered by induction for very short periods of time suggest that stresses are being adequately relieved during short-time tempering.

In the stress relaxation experiments on three slit rings of 4130 steel tempered for 5 sec., 60 sec., and 1 hr., the change in the width of the gap for each ring was considered as directly proportional to the relief of residual stresses originally produced by inductively hardening the ring. To establish a base representing complete release of residual stresses, the rings were tempered for 2 hr. at 1200° F. Further tempering produced no change in the width of the gaps. It will be noticed in Fig. 5 that the ring tempered for 1 hr. shows no further movement after tempering at 1100° F., while the 5 and 60-sec. tempering treatments apparently do not produce 100% stress relaxation at any temperature below the transformation range, although the values of relaxation are 96 and 99%, respectively, at 1300° F. Figure 5 also shows hardness-tempering curves for the three tempering times.

Figure 6 shows a plot of Rockwell C hardness versus percentage stress relaxation. The curves for the three tempering times lie close enough together to indicate that relief of residual stresses is related to the hardness for short-time as well as for long-time tempering. Thus, in this instance,

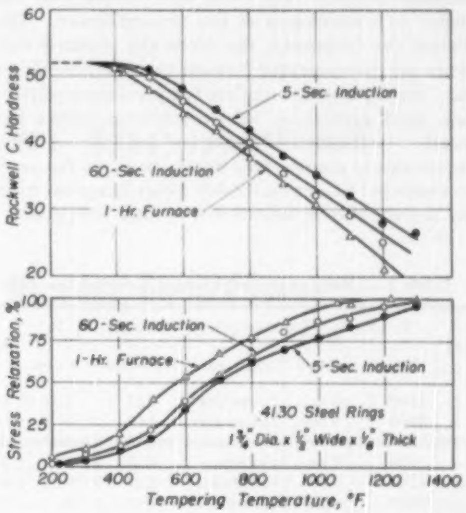

Fig. 5 — Stress Relaxation and Hardness for 4130 Steel Rings Hardened by Induction and Then Slit

the hardness may be used as a practical measure of stress relief, even for tempering cycles of only a few seconds duration.

Size Effect — In normal furnace tempering, steel is held at temperature to permit thorough penetration of the heat and uniform temperature throughout the cross section. The question naturally arises whether short tempering cycles at elevated temperature associated with induction

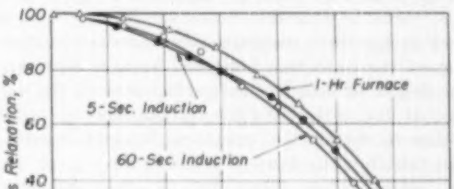

Fig. 6 — Stress Relaxation Versus Hardness

heating can provide uniform conditions throughout the cross section of the workpiece and, if not, what the effects of selective surface tempering may be on the properties of the workpiece.

In a given specimen heated by induction, the induced currents vary from zero intensity at the center to a maximum at the circumference. The higher the frequency, the more the induced currents are concentrated toward the surface of the bar. In any event, complete temperature equalization must depend on heat conduction within the metal. With high frequencies and power, it is reasonable to assume that the surface of a bar may be tempered to a considerably lower hardness than the center, that is, selectively surface tempered.

Table I — Hardness and Impact Energy for 4150 Steel

No.	Tempering Treatment*			Hardness, R_C		Impact Energy, ft-lb.
	Temp.	Time	Method	Surface	Center	
1	1000° F.	0 sec.	Induction	47.1	53.5	235, 205
2	1000	0 sec.	Induction	47.1	50.8	185, 220
3	880	1 hr.	Furnace	48.6	48.6	245, 223
4	880	1 hr.	Furnace	47.0	47.0	203, 185
5	1200	0 sec.	Induction	39.8	45.0	365, 400
6	1200	0 sec.	Induction	41.2	47.1	320, 310
7	1040	1 hr.	Furnace	39.8	39.8	355, 405
8	1040	1 hr.	Furnace	39.8	39.8	335, 385

*Specimens (1-in. dia.) water cooled from tempering temperature.

Vickers hardness readings taken on cross sections of the impact specimens (0.450-in. diameter) heated by induction at a rate of 150° F. per sec. to temperatures between 200 and 1300 °F. for 5 sec. indicated no variation from surface to center. For specimens of this size and the conditions of heating described, uniform tempering was obtained.

To develop and study the influence of surface tempering, 1-in. round, cantilever-beam impact specimens, as described previously, were prepared. Vickers hardness readings taken across the diameter of the induction tempered bars to determine the degree of selective tempering showed the centers of the 1-in. bars to average only 5 points higher in Rockwell C hardness than the surface. The total heating time to 1000° F. was 11 sec. and to 1200° F., 14 sec. These data illustrate the rapidity of heat flow within the steel itself. It was estimated from the hardness differential that a maximum temperature difference of 150° F. existed between the surface and center.

Results of the impact tests are enumerated in Table I. It is evident that while a hardness gradient existed in the 1-in. impact specimens, this gradient did not influence the impact resistance of these specimens as determined at room temperature. That is, values of impact energy absorbed by induction tempered specimens were similar to those for specimens of equal surface hardness, tempered uniformly in the furnace for 1 hr.

More rapid heating rates are required to produce marked surface tempering. What the effect of more severe hardness gradients may be on physical properties requires additional study. However, it seems possible that selective surface tempering may provide a useful combination of properties for practical application.

Conclusions — For very short tempering cycles produced by induction heating, the parameter $T(c + \log t)$ may be used with small deviations at elevated temperature to predict the hardness.

The tensile properties of plain carbon and low-alloy steels quenched and tempered to a tensile strength less than 200,000 psi. seem to be a function of hardness, regardless of the tempering cycle employed. The validity of this conclusion has been extended to tempering cycles of only a few seconds duration. The properties studied include tensile and yield strengths, elongation and reduction of area.

In the tests conducted, relief of residual stress seems to be a function of the tempered hardness for short-time tempering treatments as well as for conventional tempering cycles. This observation applies to ring specimens of the given plain carbon and low-alloy steels tempered after quenching.

Uniform hardness may be produced in ½-in. cross sections by induction tempering quenched structures at relatively rapid heating rates (150° F. per sec.) with no holding at the tempering temperature. Although rapid tempering using very high heating rates or pieces of large cross section causes a variation in hardness between the surface and center of the piece, this selective tempering effect does not seem to be detrimental, provided the proper surface hardness is obtained. Impact specimens of equal surface hardness gave similar results in spite of higher hardness at the center of induction tempered specimens.

Selective or differential tempering of the surface may provide an interesting and useful combination of mechanical properties for practical application.

The use of induction heating for short-time tempering cycles appears practical, provided the temperature is increased to compensate for the short time. Hardness may be used to control such a tempering operation.

The article presented here is based on a survey made by Dr. Swartz for the NEPA Project (Nuclear Energy for Propulsion of Aircraft), who finds that massive pieces weighing up to 1000 lb. can be produced, and the metal is workable, hot or cold, by conventional methods.

Present Status of the Art of Molybdenum Fabrication

Editor's Introduction: Molybdenum has long been used in the electrical industry for small parts such as filaments, electrodes, grids, contacts and supports. These specialized uses would recede into relatively minor importance if the metal's full possibilities for structural use at high temperature could be realized. It is the potential application of molybdenum and molybdenum-base alloys in large parts for heat engines that lends current interest to the subject of molybdenum fabrication. Chief deterrent to such use is the lack of a satisfactory method for protecting the surface of molybdenum against oxidation at high temperature.

The present line-up of high temperature alloys, in order of increasing strength near 1500° F., is: iron-chromium-nickel, nickel-chromium base, nickel-molybdenum base, cobalt base, and chromium base. The static tensile properties of unalloyed molybdenum, as tabulated on p. 200-B of this issue, are encouraging — for example, a yield strength of 40,000 psi. in short-time tests at 1800° F. When the surface protection problem is solved and appropriate molybdenum alloys are developed, molybdenum may take its place as our strongest high-temperature metal. [From here on the article is Dr. Swartz's.]

Knowledge and experience with respect to the fabrication of molybdenum are becoming available in ever-increasing amounts. A number of organizations are now in a position to produce molybdenum articles that have been either drawn, spun, bent, or joined mechanically. Brazing methods which give tight, nonbrittle joints are available. At least one molybdenum-to-molybdenum weld that showed considerable ductility in spinning has been made.

Several concerns are eager to take orders for parts or completed units for which molybdenum is specified. It is assumed that what may be needed now is the skill which comes only with varied and extensive experience. In other words, it is probable that further extensive experimental work for the development of fabrication techniques will be done only when specific parts are placed on order by the various users.

Primary Molybdenum Production

Massive sintered molybdenum is being produced by Fansteel Metallurgical Corp., General Electric Co. and Westinghouse Electric Corp. Massive sinterings of molybdenum and molybdenum-rich alloys, measuring up to 6 in. square, 4 ft. long, and weighing over 400 lb., have been

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produced. After heat treatment, the densities of these pieces are essentially those of cast or melted ingots. Square or rectangular slabs have been produced to facilitate rolling so that the preliminary forging step is eliminated. The pieces so made are rolled directly with no machining or cutting away; hence, there is no excess metal to recover. The size of the rolling mill available limits the size of piece that may be fabricated at the present time.

The statements mentioned also apply to alloys containing small percentages of cobalt and nickel. Much experience with the fabrication of rod, strip and plate is now available for alloys containing as high a percentage of cobalt or nickel as can be readily rolled or fabricated.

The existing units at the Westinghouse Electric Corp. are capable of producing heat treated rectangular pieces 5 ft. long, weighing 700 lb., or rounds 5 ft. long, weighing approximately 1000 lb. While there has been no demand for massive pieces of such sizes, pressing equipment and furnaces are available.

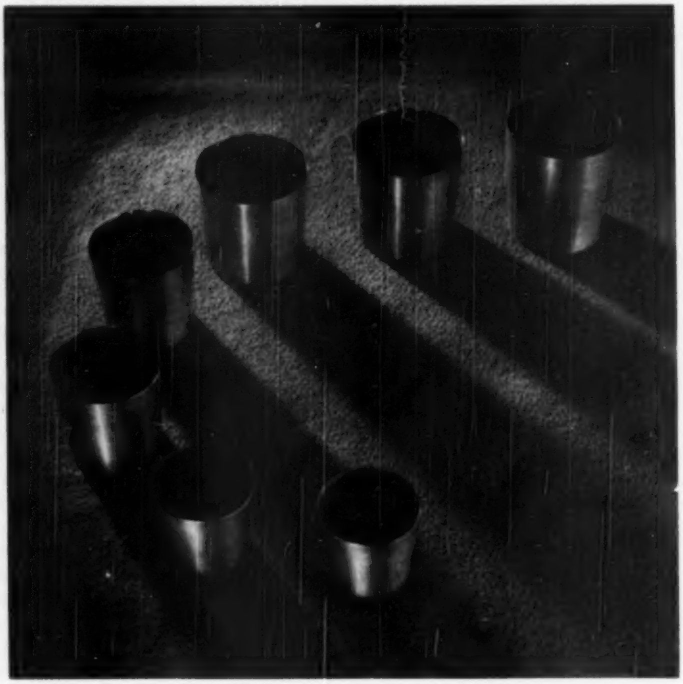
Many heat treated tubes and special shapes made by the use of the hydrostatic pressing technique can be produced when requested. Still larger pieces could be produced by utilizing a larger pressing cylinder. In general, the sizes and shapes that can be formed hydrostatically are limited by the availability of adequate pressing cylinders.

Cast molybdenum ingots up to 6 in. in diameter and weighing 190 lb. have been produced regularly by the Climax Molybdenum Co. After being machined to 5½ in. in diameter (165 lb.), these ingots are forged to 2 or 2½ in. and annealed as the metal work hardens. From this size, the metal is rolled in standard toolsteel passes to various rod sizes. The billets may also be rolled into sheets and strips, drawn into wire or extruded into tubing. Alloy ingots containing from 2 to 5% tungsten are also cast; in fact, most of the material now being tested is the 2% tungsten alloy.

A small melting unit that produces ingots 2 in. in diameter and 10 in. long is being used for research on molybdenum alloys. A new unit is being built, and before the end of 1950 it is expected that ingots up to 9 in. in diameter and weighing about 1000 lb. will be cast. With additional power, the same unit should produce 12-in. ingots weighing 2000 lb.

Working of Molybdenum

Breakdown — The cast or sintered structure of molybdenum may be broken down by rolling or forging. Rolling seems to be the preferred technique for the sintered product since it is usually produced in a rectangular cross section, whereas the cast ingots, made in round sections, are forged initially. The sintered material is rolled directly, with no machining; cast molybdenum is turned down to a smooth surface before being forged. Although the metal may be worked at temperatures between 1700 and 2000° F., castings of either pure molybdenum or a low-tungsten molybdenum alloy are broken down at temperatures of 2400 to 2500° F. and then reworked at 2400° F.

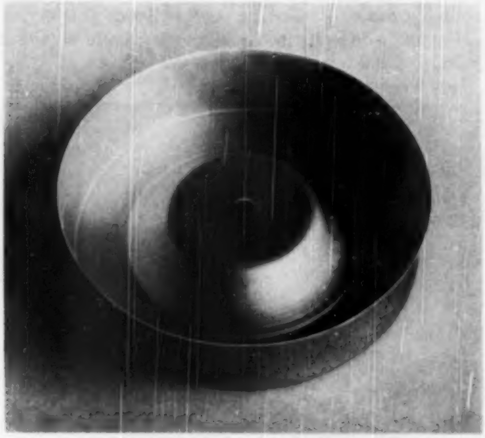


Molybdenum Crucibles Spun by Lamp Division of Westinghouse Electric Corp., Some From Fairly Heavy Sheet

Forging — Flat forgings having a 5-in. diameter can be produced with relative ease; however, the size and power of the equipment used limits the finished product. The problems encountered in working large pieces are, therefore, essentially those of having or obtaining equipment of sufficient size and possessing enough experience and technical knowledge to make a final product that is both free from cracks and flaws and is ductile enough for further fabrication.

Molybdenum is also available in small forgings having a diameter of 2½ in. or less.

Rolling of Rod — Bar and rod are rolled at 2100° F. in standard toolsteel passes and annealed when necessary to remove work hardening.



Support for Molybdenum Furnace Liner Fabricated From 0.030-In. Sheet by Spinning. Note the sharp angle at the bottom which would have been difficult if the part had been fabricated by drawing. Sheet of this thickness is spun at about 300° F. Tools are also heated to avoid chilling the work (Courtesy Fansteel Metallurgical Corp.)

Rolling of Sheet — Sheet may be cold rolled to various gages, down to 0.001 in. Hot rolling is usually done at temperatures below 1950° F. In single-thickness rolling, sheet is reduced to as low as 0.0625 in., whereas in pack rolling the reductions have been made to a gage of 0.010 in.

Straight rolled and cross rolled sheet in sizes up to 0.020 x 24 x 60 in. have been produced, and some rolling has been done on pieces approximately 6 in. thick and 4 ft. long. Processes are known which will give a good degree of ductility both in the direction of rolling and across flat pieces ½ to 1 in. thick.

Production of Tubing — Seamless tubing is being made by extrusion and drawing to size. This tubing is available in dimensions from ½ in. o.d. downward in a number of wall thicknesses.

Spinning — Molybdenum can be spun successfully into many shapes when heated to a temperature of about 400° F. Annealed, cross rolled material may be used. Two of the producers who have experience in molybdenum spinning are Westinghouse's Lamp and Tube Parts Div. at Bloomfield, N. J., and G. E. Nelson, Holly, Mich.

Deep Drawing — Some deep drawing has been done at Eisen Metal Products Co., Lodi, N. J., with wall reductions between anneals up to 22%.

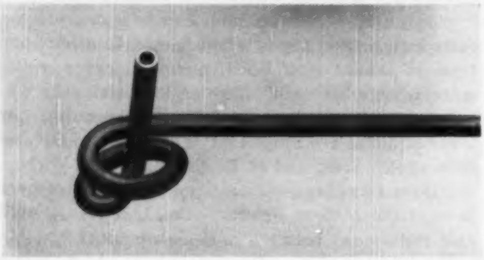
Cold Forming — Experienced sheet metal workers can do "considerable" forming and bending of molybdenum. For example, a 0.010-in. thick sheet may be bent tightly on itself without breaking. However, such a sheet may fracture when attempts are made to straighten it. Lock-seam joints can be made, and various punching, stamping and forming operations may be carried out. Moderate heating is beneficial in these operations.

Welding and Brazing

Considerable experimentation with respect to welding methods for molybdenum must be done before it can be said that the molybdenum welding problem is solved and under control. Currently, gas-tight welds that will stand small shear and bending stresses can be produced, and these welds are probably capable of withstanding higher loads at elevated temperatures (say 1000° F.). There is some evidence to indicate that welds may be improved by preheating before welding and cooling very slowly after the weld is made, or by utilizing the parts at elevated temperatures without cooling. On the other hand, one authority stated that a small butt-welded cylinder could be spun into a shape similar to a venturi without cracking at the weld. In this particular example, helium-shielded arc welding was used, with the torch hooded to allow only inert gas to come in contact with the weld.

Molybdenum may be brazed with silver brazing alloys or with platinum, palladium, or molybdenum eutectic alloys. Nickel in the brazing alloy is helpful. A nickel electroplate on the molybdenum surface where brazing is to be done may also be used. One of the best brazing alloys, where strength and oxidation resistance through at least 2000° F. are needed, is "Wall-Colmonoy No. 6" (essentially an Inconel containing 2 to 3% boron). No brazing alloy is known that will withstand the conditions encountered when siliconizing is done after brazing.

Cooling Coil Formed From 3/8-In. Outside Diameter Seamless Molybdenum Tubing. Tubing was heated before bending. (Fansteel Metallurgical Corp.)



Surface Protection at High Temperatures

Molybdenum and molybdenum-rich alloy surfaces must be protected where oxidizing conditions exist at 800° F. and higher for periods longer than several minutes, dependent on temperature and permissible loss in thickness of molybdenum.

To prevent oxidation at elevated temperatures the following methods have been suggested:

Hot Dipped Aluminum Coating — Experience thus far indicates that this coating is unreliable. On occasion, it has been known to protect molybdenum from oxidation for several hours at temperatures where molybdenum oxidizes rapidly, but as yet no technique has been developed to assure reproducibility of this behavior.

Cladding — Some success has been attained in coating molybdenum with nickel or Inconel by means of roll bonding techniques. Thus far, Inconel coating has shown more stability than nickel. One Inconel-coated specimen has been held at 2000° F. for more than 400 hr. (test still in progress). All failures thus far have been at the welds used to seal the edges. Electroplated nickel coatings have also shown promise.

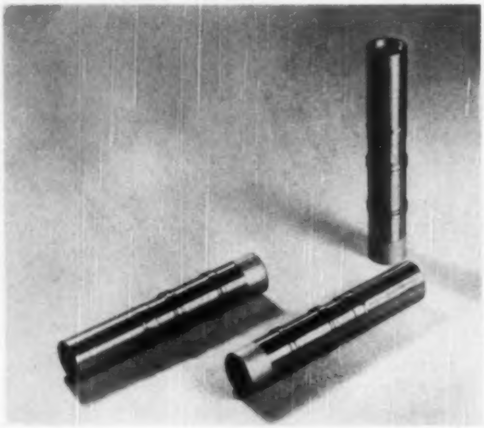
Molybdenum Disilicide — This coating has shown much success in several applications. Although brittle, it does withstand some deformation without exposing the molybdenum. For example, riveting may be done with coated rivets without damage to the coating, and probably 1% elongation can be given a coated sheet without damage to the coating. Apparently, the coating is formed above the recrystallization temperature of the molybdenum so that the coated stock is limited to the properties of the annealed material. At the present time, there is a size limitation for this process which appears to be of the order of about 6 in. in the longest dimension.

Enamels — So far, enamels have not stood up well in tests.

Molybdenum Alloys

A number of molybdenum binary alloys have been studied but further work must be done before detailed conclusions may be drawn. Binary alloys of aluminum, boron, beryllium, cobalt, chromium, columbium, iron, nickel, titanium, vanadium, uranium, tungsten and silicon have thus far been produced for experimental study in the Climax Molybdenum Co. melting unit.

Nickel is the most potent binary alloying agent thus far studied for increasing the hardness of molybdenum, cobalt is next in value, and aluminum shows some promise. Much more work must be done on these alloy systems before the preliminary exploration is finished and the proper conclusions drawn. Nickel, cobalt and iron seem to be promising alloying agents from the standpoint of increasing hardness and tensile strength at elevated temperatures. In this respect, tungsten has less utility. Low-nickel and low-cobalt alloys produced by powder metallurgical methods have been studied extensively but published results are not available as yet. In the course of this work, a vast number of hardness and tensile determinations were carried out. Low-alloy molybdenum compositions apparently present no problem; they are fabricated every day.



Electronic Tube Parts Fabricated From 7/8-In. Diameter Seamless Molybdenum Tubing by Machining and Grinding (Fansteel Metallurgical Corp.)

Editor's Footnote — Information on the machining of molybdenum is given in an article by Jack Chelius of Fansteel Metallurgical Corp. in July 1950 issue of *Materials and Methods*.

There have been many recent papers on the physical and mechanical properties of titanium and zirconium — either pure, slightly impure, commercially pure, purposely alloyed, or hopelessly contaminated. The practical metallurgist has been waiting for some informed comment about the fabrication of these metals under shop conditions. Here it is.

Fabrication of Titanium and Zirconium

IN ORDER to fabricate titanium and zirconium intelligently, it is necessary to have a clear understanding of the great importance of small amounts of impurities, which are easily picked up by these reactive metals during their primary production.

The purest and most ductile titanium or zirconium is obtained by the iodide method, and such metal can absorb tremendous amounts of cold work without fracture, provided only that the work is introduced in steps rather than all at once. For example, by using a large number of rerolling steps, very pure iodide zirconium has been reduced from a bar $\frac{3}{16}$ in. in diameter to strip as thin as 0.005 in. without annealing, and the strip retained considerable ductility.

The metal in widest commercial use is produced as "sponge" by magnesium reduction of titanium or zirconium tetrachloride, a process less costly than the iodide method. After the sponge metal has been remelted in graphite, it contains from 0.5 to 1% carbon but is relatively low in nitrogen and oxygen. Titanium and zirconium that have been melted in a water-cooled copper mold are the most workable of the commercial products from sponge, but naturally are of lower strength than when produced by a method that introduces carbon, nitrogen and oxygen.

A few hundredths or a few tenths of a per cent of nitrogen or oxygen alters the properties of both titanium and zirconium about as drastically as steel is altered by carbon up to the eutectoid composition. Below about 0.25%, increasing carbon content has a marked strengthening effect on titanium; the accompanying loss in ductility is appreciable but not prohibitive. Above about 0.25%, carbon adds little to strength and considerably reduces workability. The difference in the effects of melting titanium or zirconium in carbon crucibles, as compared with melting in water-cooled copper molds, is much greater than the difference between melting steel in a bessemer converter or an electric furnace. It is well for the metallurgist to remember that when either titanium or zirconium contains more than about 0.03% carbon, oxygen or nitrogen, these metals are *alloys*, just as truly as low-carbon steel is an alloy of iron and carbon.

The general trends of carbon, nitrogen and oxygen contents of magnesium-reduced titanium

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Fig. 1 — Titanium Tubing That Has Been Redrawn, Flared, Flattened, Crushed and Bent

melted by the several available methods are as follows:

Melted in Graphite, Under Vacuum — High carbon, low oxygen and nitrogen.

Melted in Graphite, With Inert Gas Atmosphere — High carbon, medium oxygen and nitrogen.

Melted in Water-Cooled Copper, Under Vacuum — Low carbon, oxygen and nitrogen.

Melted in Water-Cooled Copper, With Inert Gas Atmosphere — Low carbon, medium oxygen and nitrogen.

Except where otherwise noted in the text, the results reported here apply to metal with low carbon, oxygen and nitrogen contents, such as heats A and C in Table I.

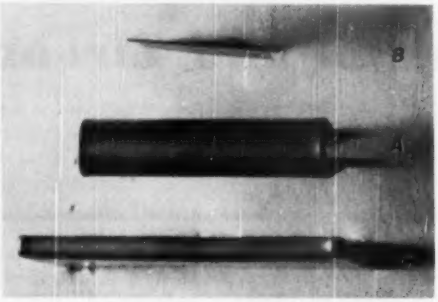


Fig. 2 — Bend Tests on Titanium Sheet. Specimen from heat A (0.050 in. thick) was bent parallel to the direction of rolling, on a radius three times the thickness. Specimens B (0.008 in.) and C (0.065 in.) were bent perpendicular to the direction of rolling, on radii twice the thickness. Compositions are given in Table I

The hexagonal crystal structure of both titanium and zirconium is another basic fact that needs to be recognized in considering the mechanical fabrication characteristics at room temperature. Hexagonal metals display only one active plane of slip at or near room temperature. This is true whether the metal be titanium, zirconium, magnesium or zinc. An increased number of slip planes become available as the temperature of an hexagonal metal is raised; thus, the workability of titanium and zirconium is increased at temperatures above 400° F. It should be emphasized that this is a characteristic of the crystal structure and one not likely to be changed by alloying, except when alloy additions are large enough to depress the transformation temperature below room temperature. If that can be done, we may expect a highly workable face-centered cubic series of alloys that should behave like copper, nickel or austenitic stainless steel.

Bending, Drawing and Forming — When compared with magnesium, both titanium and zirconium exhibit superior room temperature fabricating properties, as evidenced by the flaring, bending and flattening of the welded and drawn titanium tubing of low carbon, oxygen and nitrogen contents shown in Fig. 1.

Figure 2 shows bend tests applied to annealed titanium strip of similarly low impurity contents.* Other "commercially pure" titanium having higher carbon, nitrogen and oxygen contents seldom permits a 180° bend on a radius less than three or four times the thickness, and such material often cracks before it has gone much beyond 90°.

As an illustration of the deep drawing characteristics of these metals when in the really pure and ductile form, the results of Olsen cup tests are given in Table II.* These were applied to low carbon-nitrogen-oxygen titanium 0.067 to 0.003 in. thick, the latter after 50% cold reduction.

Similar tests on annealed high-purity zirco-

*These results from Titanium Metals Corp.

Fig. 3 — Impact-Extruded Zirconium. These cups are unsatisfactory because extruded directly from an iodide-deposited bar that lacked proper intercrystalline cohesion (Courtesy of General Electric Co.)

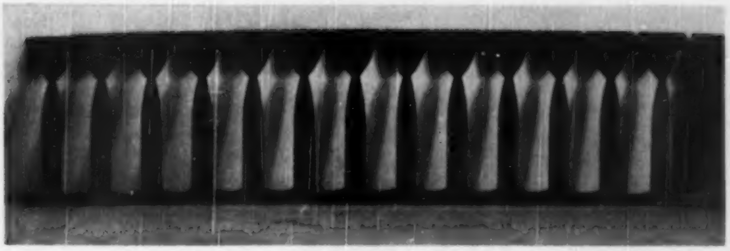


Fig. 4 — Titanium, Edge Rolled and Blanked

nium sheet of thicknesses from 0.020 to 0.005 in. yielded cup depths from 0.270 to 0.424 in. (hardness was from 74½ to 79 on the Rockwell 15T scale). These cup test results are equal to, and in some cases better than, those obtained with commercial deep drawing stock of stainless steel and nickel. It must be noted, however, that zirconium proved to be extremely sensitive to draw-ring radius, requiring a greater radius than the usual deep drawing sheet. It is our understanding that titanium exhibits a similar characteristic.

The iodide form of zirconium, at least, seems amenable to impact extrusion (Fig. 3). This figure requires explanation: The samples were extruded direct from iodide-deposited bar in which there was some lack of intercrystalline adhesion, an unpredictable condition sometimes encountered. The photograph demonstrates the general workability of the metal by impact extrusion, even though these particular results were unsatisfactory.

Table I — Titanium Used in Bend and Cup Tests

	C	N	Fe	Si	Ti
Heat A	0.04	0.07	0.12	0.02	99.7
Heat B	0.02	0.18	0.07	0.05	99.6
Heat C	0.015	0.07	Trace	0.024	99.9

Oxygen analyses not available; specimens high in nitrogen are usually high in oxygen also.

Table II — Olsen Cup Tests on Titanium Sheet

Heat*	Thickness	Temper	Rockwell Hardness†	Olsen Reading
A	0.067 in.	Annealed	B-96	0.333 in.
A	0.050	Skin rolled	B-96½	0.325
B	0.003	Hard	15T-91½	0.120
B	0.008	Skin rolled	15T-89	0.290
C	0.065	Annealed	B-75	0.400+

*Compositions of heats are given in Table I.
†Corresponding tensile strengths (psi.) and elongations (% in 2 in.) were: 86,500, 25; 90,000, 21.5; 116,800, 5.8; 74,900, —; and 55,300, 30.

Stretch forming has been successful on titanium sheet of higher carbon content and consequently lower ductility. Blanking and edge rolling of thin strip are shown in Fig. 4.

Galling and seizing characteristics are exceedingly troublesome in drawing and machining. Seizing is particularly severe with titanium, as evidenced in the cold drawing of tubing and wire. It has been reduced by purposely oxidizing the surface to prevent metal-to-metal contact; however, this practice can result in embrittlement. Metallic and solid-type resinous lubricants have been found which supply adequate lubrication for such operations.

For reasons not altogether evident, the galling characteristic of titanium does not seem to be nearly so severe during machining operations. Figure 5 shows a bar of low carbon-oxygen-nitrogen titanium which has been deep drilled to an 18-in. depth, lathe turned and threaded on the outside diameter with a standard pipe thread die and on the inside diameter with a standard high speed tap. The bar has been slit lengthwise with a very thin milling cutter. All of these operations were lubricated with ordinary cutting oils and the only difficulty encountered was the need for very frequent chip clearing when the internal thread was being tapped.

Undoubtedly further experience with titanium and zirconium will bring about the evolution of tool angles and grinding techniques particularly adapted to these metals. It should be remembered that tool forms best suited to steel were not well-adapted to nickel alloys, aluminum, stainless steel and magnesium when these newer materials came along, and it is not to be expected that titanium and zirconium can be machined most efficiently with the same tool designs as the common metals.

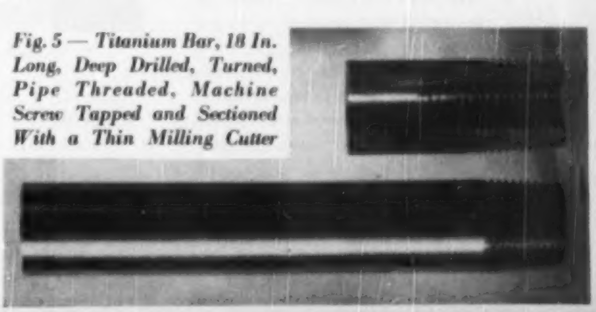


Fig. 5 — Titanium Bar, 18 In. Long, Deep Drilled, Turned, Pipe Threaded, Machine Screw Tapped and Sectioned With a Thin Milling Cutter

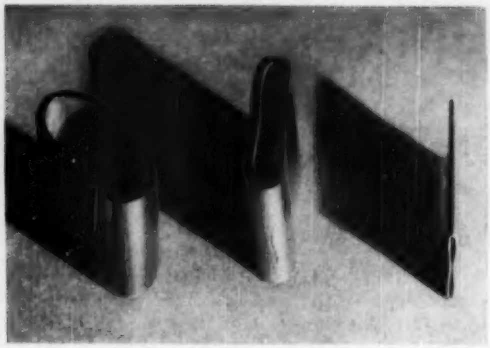
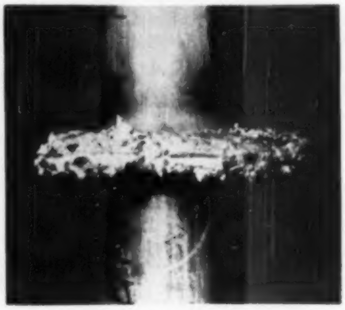


Fig. 6 — Flattening Tests on Welded Titanium Tubing. Left to right: As welded, welded and annealed, and redrawn and annealed

Welding — The affinity of titanium and zirconium for nitrogen, oxygen and carbon obviously indicates the need for some special welding techniques. Fusion welding of tubing, for instance, is done under an ample blanket of carefully controlled inert atmosphere. The technique is exacting if ductile welds are to be made because the weld must be protected both inside and outside to prevent gas absorption. Metal adjacent to the weld which attains a temperature of more than about 1000° F. must be equally well protected.

Just as in the welding of many other metals and alloys, the composition of the parent metal is quite as important as the control of the welding process. It is believed that some reports of brittle welds have had their origin in the use of metal high in one or more of the elements nitrogen, oxygen or carbon. Other difficulties also seem to be the result of the absorption of nitrogen, oxygen and hydrogen during welding. Flattening tests performed on titanium tubing as welded, as welded and annealed, and welded, redrawn and annealed are shown in Fig. 6.

Zirconium has not yet been extensively welded, so there is less known about its characteristics. However, because zirconium is more reactive than titanium it would be expected that protective measures would need to be even more stringent. Butt welds that have been made between very thin zirconium sheets, using the inert-arc process, indicate that joints of satisfactory strength can be produced by this method.



As-Welded Bar

Section Through Weld

Fig. 7 — Titanium Bar, Flash Butt Welded (Courtesy American Welding and Manufacturing Co.)

Resistance welding of both the spot and flash varieties is readily accomplished in titanium but it is much more difficult to protect this type of weld from gas absorption. A flash-butt-welded bar is shown in Fig. 7, along with a section through the weld. There was no evidence of an oxide line, even when the microstructure was examined at 500 ×.

To date, successful welding of titanium and zirconium to dissimilar metals has not been reported, but it has been reported that titanium may be brazed to dissimilar metals with alloys of titanium-copper and manganese-nickel.

Summary

It is manifestly impossible to cover all of the pertinent details of fabrication procedure on titanium and zirconium in so short an article. In summarizing, we would emphasize that it certainly is not our intention to discourage anyone from performing all of the normal metal-working operations on these two new metals. As our few illustrations have shown, all of these operations are feasible. But let it be remembered that these metals are different from the common metals — all of the reactive gases are absorbed and most of them cause embrittlement; below about 1600° F. titanium and zirconium are hexagonal in crystal structure and their working properties are governed by that fact; they gall and seize readily but the tendency can be controlled. Titanium particularly is destined to become important and its destiny will be more rapidly fulfilled if we design our processing to fit the properties of the metal and do not try to force titanium into a conventionalized pattern dictated by fabrication practices used on the common metals.

(Annealing will be considered in a later article.)

Commercial titanium with 0.78% carbon has been hammer forged successfully in the temperature range from 1875 to 1450° F. with regular production equipment. Experimental drop forgings have also been produced.

Hot Forging of Commercial Titanium

THE recent increases in the size of titanium ingots that are commercially available — first to 100, then to 400 lb. — have made the material of interest to the heavy metal working plants. These commercial ingots are melted in carbon crucibles under an atmosphere of inert gas. Carbon is consequently present in amounts which may range up to 1%, or even beyond. The uniformity of carbon distribution in the large ingots is excellent.

Titanium undergoes an allotropic transformation at 1625° F. from the low-temperature hexagonal structure to the high-temperature body-centered cubic structure. The obvious analogy to steel metallurgy makes attempts to improve the properties by heat treatment or well-chosen working techniques very attractive. The great reactivity of titanium at elevated temperatures has caused most investigators to handle it in vacuum. At the Naval Gun Factory, we deliberately did not, in an effort to see what ordinary commercial practice could accomplish with massive titanium.

The Metal—An 87-lb. ingot of DuPont titanium was the starting material in our forging operations. The ingot was made by induction melting of sponge titanium in a graphite pot under argon atmosphere and bottom pouring into a graphite mold. Figure 1, on the next page, shows the ingot as received. The bottom and sides were covered with a hard black scale.

The following chemical analysis was supplied by the DuPont Co.: 98.77% titanium, 0.12% iron, 0.74% carbon and 0.06% nitrogen. Analysis by the Naval Gun Factory showed 0.78% carbon in each of several locations from edge to center, provided the surface scale was removed. The Brinell hardness (10-mm. carbide ball, 3000 kg., 30 sec.) varied from 241 at the top, 1 in. from the side, to 262 at the bottom center. Radiographic examinations made by means of a million-volt X-ray machine showed the ingot to be sound. Macro-examination of a cross section of the ingot ⅜ in. from the top revealed a homogeneous, fairly coarse-grained structure, with a few small voids near the edge (Fig. 2).

In order to eliminate any questions about the suitability of the as-received surface for forging, all surface imperfections were removed by machining ⅜ in. of metal from the sides, top, and bottom with a carbide-tipped tool. Machining proceeded satisfactorily but slowly. After machining, the ingot was 10¼ in. high, 7¼ in. in diameter and weighed 66 lb.

Drop forgings were made from 6 x 1 x ⅝-in. blanks cut from ⅝-in. rolled plate of titanium manufactured by the Remington Arms Co. The carbon content of this plate was 0.18%.

Flat Die Forging—Oil-fired furnaces were used to bring the metal to forging temperatures.

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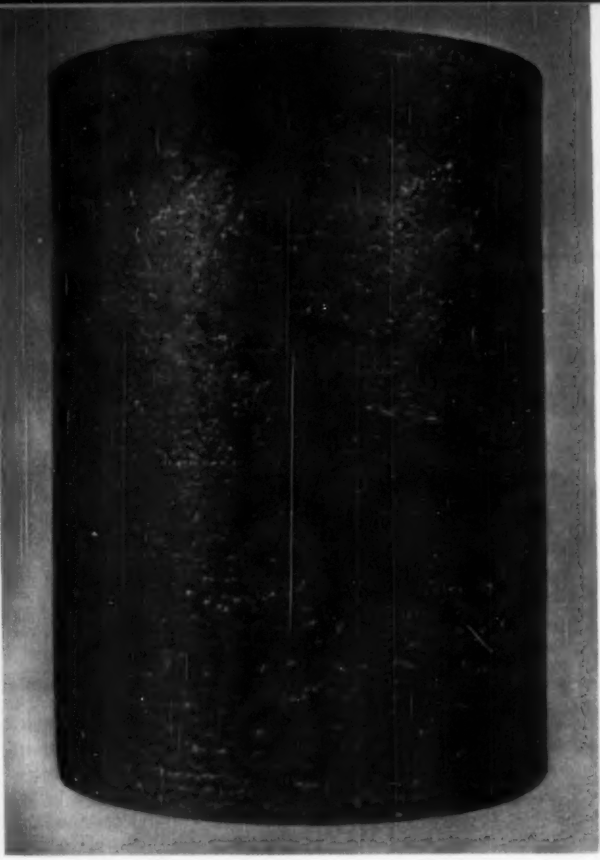


Fig. 1 — As-Cast Surface of 87-Lb. Ingot of DuPont Titanium, 11½-In. High, 8-In. Diameter

The ingot was first charged into a furnace held at 850° F. and preheated for 1 hr. It was transferred to a furnace at 1875° F. and held there 1½ hr. until brought to temperature, as indicated by an optical pyrometer. The hot ingot was then placed under an 8000-lb. Erie steam drop hammer. After five preliminary blows in the direction of its longitudinal axis, the ingot was turned on its side. Forging was continued until the thickness had been reduced to about 3 in. and the temperature to about 1400° F., when edge cracking began to appear. The billet was immediately reheated to 1875° F. and the edges were hot trimmed to remove the cracks and bursts. Shallow transverse cracks were noted on one flat side. The billet (3 x 12 x 8 in.) was allowed to cool. Cracks and torn metal were removed by chipping and grinding.

The billet was reheated to 1875° F., worked under a 6000-lb. Chambersburg forging hammer and reheated to 1875° F. whenever its temperature approached 1400° F. Small bites about ⅛ in. deep were made across its width. Surface cracks developed on the bottom die side during the first pass across the billet and deepened during the second pass. It was then allowed to cool and was ground until fluorescent penetrant (Zyglo) testing failed to show any cracks. At this point the dimensions were 9¼ x 16½ x 2¼ in. Heating to 1875° F. and working in

Fig. 2 — Macrostructure of Titanium Ingot ⅜ In. Below Top. Etched with HF, HNO_3 and glycerine

the same manner were resumed until dimensions reached 25 x 9¼ x 1½ in. The air cooled slab, weighing 55 lb., was sound by radiographic and reflectoscope tests.

Rolling and Hot Straightening — The forged slab was shipped to a commercial mill and hot rolled at right angles to its long axis until ⅝ in. thick. Unfortunately, no record was made of the rolling procedure. Flatness was not satisfactory, so the plate was pressed flat by the Naval Gun Factory at 1850° F. under an 800-ton hydraulic forging press. It was cooled in still air and cleaned by hydroblasting, then X-rayed and found to be sound. The final size was 20 x 24 x ⅝ in. Brinell hardness was 228 to 236.

According to information received from representatives of the DuPont Co., no piece of titanium as large as this ingot had been forged up to the time of these experiments (October 1949). The results indicate that large masses of titanium can be forged commercially. It is believed that edge cracking and bursts can be eliminated as the forgers gain experience with this metal. Reductions by forging should be made in small light steps to prevent cracking. Initial breakdown might well be under a press rather than a hammer.

Drop Forging — The 6 x 1 x ⅝-in. blanks for drop forging were heated in an oil-fired open-fire forge furnace. They were placed in a cold furnace, heated to 1850° F. and soaked for 15 min. They were then given five blows (three for breaking down, one for rough finishing, and one for finishing) in an 800-lb. board drop hammer. Finishing temperature was 1650° F. The pieces were then trimmed, reheated to 1850° F. and given one light finishing blow. The yellowish white scale which covered the forgings after cooling to room temperature was removed by hydroblasting. Visual and radiographic examination revealed no defects. Figure 3 shows the completed drop forgings.

Fig. 3 — Titanium Drop Forgings. Half size

Dies used for the titanium forgings were the ones normally used for steel. Comparative dimensional measurements showed less shrinkage in the titanium drop forgings during cooling to room temperature than in similar forgings made of steel:

Dimension No.	Steel	Titanium
1	0.635 in.	0.641 in.
2	0.388	0.396
3	0.382	0.386
4	0.259	0.267
5	0.261	0.266

Mechanical Tests — Small slugs approximately ½ in. in diameter by ½ in. long were machined from the forged and hot rolled plate and compressed cold. A reduction of 50% could be obtained in this manner before cracking occurred, and this reduction increased the hardness 10 points Rockwell G. Results of the compression tests are given in Table I. Table II shows tensile properties of the forged and hot rolled plate.

Table I — Compression Cold Work Tests of Forged and Hot Rolled Titanium Plate

Specimen	Unit Load*	Reduction in Thickness	Rockwell G Hardness
0	0	0	81.5
1	137,000 psi.	6.3%	82
2	152,000	10.4	85
3	174,000	15.0	87
4	197,000	20.2	87.5
5	252,000	30.7	88.5
6	289,000	40.0	90
7	354,000	50.3†	91

*Based on original cross-sectional area. †Cracked.

Table II — Tensile Tests of Forged and Hot Rolled Titanium Plate

Direction	Proof Stress,* Psi.	Yield Strength,† Psi.	Tensile Strength, Psi.	Elongation‡	Reduction in Area
Longitudinal	59,000	73,400	101,000	8.1%	10.3%
Longitudinal	66,500	75,300	101,000	15.7	23.1
Transverse	52,000	72,000	101,000	15.7	24.3
Transverse	58,800	72,000	100,000	15.7	22.2

*Unit load at which permanent deformation reached 0.0001 in. per in. of gage length. †Unit load at which extension under load reached 0.005 in. per in. of gage length. ‡Elongation was measured on a gage length of 1.4 in. for the subsize (0.357-in. diameter) specimens used.

Yield Strength Versus Extension Under Load

For metals that do not exhibit a definite yield point, specifications generally require a minimum value for the stress at which a specified amount of permanent deformation, usually 0.2% of the gage length, occurs. This stress, known as the yield strength, can be readily obtained when equipment is available for automatically recording the so-called stress-strain diagram.

An alternate method for determining the yield strength, known as the extension under load method, which does not require that the stress-strain curve be plotted, is described and discussed in A.S.T.M. Specification E8-46, "Standard Methods of Tension Testing of Metallic Materials". Recently there has been increasing interest in this alternate method for determining yield strength. Therefore, it seemed desirable to establish whether or not there is a relationship between this method and the offset method which would make it feasible to employ either method in materials specification testing.

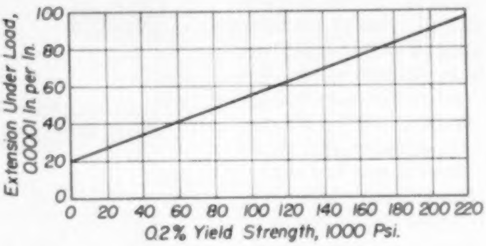
By plotting the extension under load obtained from automatically recorded stress-strain diagrams against the 0.2% offset yield strength, a linear relationship was found, as indicated by the accompanying figure. The data used resulted from the testing of miscellaneous grades of alloy constructional steels in various conditions of heat treatment with yield strengths which varied from about 55,000 to 220,000 psi.

The straight line resulting from plotting these data extrapolates to 0.0020 in. per in., or 0.2%, at zero yield strength and has a slope, the reciprocal of which is the average modulus of elasticity for the steels used in this survey. This average modulus value computed from the slope of the line is 28.6 million psi.

The figure indicates that the total strain at the yield strength can be considered to be the sum of the strain which would result from stressing a specimen elastically to the yield strength, plus the amount of the offset in inches per inch. For example, the figure shows that the total strain corresponding to a 0.2% yield strength of 100,000 psi. in a steel with a modulus of 28.6 million psi. is 0.0055 in. per in. This is made up of an elastic strain of 0.0035 in. per in. (100,000/28,600,000), plus 0.0020 in. per in., the amount of the offset. In general, the total strain for any yield strength in any material of known modulus of elasticity can be computed as follows:

$$\text{Total Strain} = \frac{\text{Yield Strength}}{\text{Modulus}} + \text{Offset in in. per in.}$$

This relationship is particularly useful in testing which is carried out to establish whether or not a given material conforms to its governing specification. Assume, for example, that it is desired to ascertain whether a particular lot of steel of a grade known to have a modulus of 28.6 million psi. has a 0.2% yield strength of 100,000 psi. minimum. The figure, which is applicable to steels with a modulus of 28.6 million psi., shows that a 0.2% offset yield strength of 100,000 psi. corresponds to an extension under load of 0.0055 in. per in. This same extension could also have been computed as described in the preceding paragraph. As the load is applied to the specimen



the extensometer would be watched, and when the strain of 0.0055 in. per in. is reached, if the corresponding computed stress is greater than the required 100,000 psi. minimum, the material is acceptable.

The advantage of the extension under load method of materials testing is that it is not necessary to construct the conventional stress-strain diagram to check for conformance with the yield strength requirement.

The figure presented is applicable to steels having a modulus of 28.6 million psi. Since the slope of the straight line simply reflects the modulus it is a simple matter to construct similar figures for any material of known modulus.

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Aluminum can now be rolled into larger plates and wider sheets than ever before in the industry's comparatively short history. This is being done in a new Alcoa plant located on the banks of the Mississippi near Davenport, Iowa.

Production of Aluminum Sheet and Plate in Large Sizes

BETWEEN 1939 and 1943, the United States aluminum capacity was increased six-fold, and a major fraction of this enlarged production of ingot metal was converted into flat rolled products for use in aircraft. Today, five years after V-J day, the aluminum industry is producing nearly as much sheet and plate as in the peak year, 1943, but most of the consumption has shifted to architectural, railway, truck, bus and other equipment applications. The industry is moving into partially exploited markets and seeking new ones. Additional plant facilities are coming into production. One of these, the Point Comfort electrolytic reduction works of the Aluminum Co. of America, was the subject of an article in last month's *Metal Progress*. Another Alcoa plant, the new sheet and plate mill near Davenport, Iowa, is described here.

The modern trend in rolling mills got its start in 1926, when the first wide, continuous coiled-strip mill was built for the steel industry. Fabricators were quick to appreciate the advantages of flat stock in greater sizes and there followed a demand for larger coils of sheet and a steady increase in the maximum width obtainable. The aluminum mills could not undertake a similar transition until the late 1930's when the aircraft industry began to show signs of bigness. Since then, the maximum width of aluminum sheet has doubled, as shown in Fig. 1.

The Davenport Works, 52 acres under roof, was designed to roll ingots approximately double the size of the largest rolling ingots produced elsewhere by Alcoa. It was designed to produce wider and longer sheets in larger coils, and bigger plates than heretofore available from any aluminum mill. But there is more to the Davenport Works than a line of wide mills. The story may properly begin with the melting department.

Melting and Casting—Melting units are designed to work in close coordination with the continuous casting facilities. This is accomplished by arranging four furnaces around each casting unit, as shown in Fig. 2. Davenport Works has five such units, with a total of 20 reverberatory furnaces. Primary aluminum pigs (weighing up to 1400 lb. each) and in-plant scrap are put into the melting furnaces by means of a mechanical charging machine and alloyed as required. These furnaces, having chrome brick bottoms and walls, with silica roofs, hold about 25 tons of aluminum and are heated by natural gas to temperatures up to

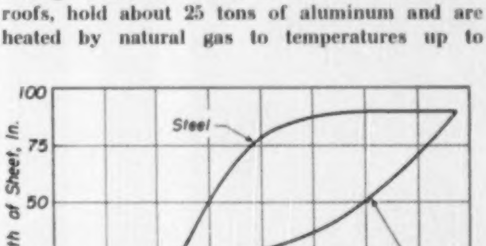


Fig. 1 — Trends in the Width of Sheet. Smoothed curves based on nominal maximum widths of coiled sheet available from production facilities

Fig. 4 (Right) — Photo Taken From Melting Furnace D (Fig. 2) Looking Toward Holding Furnace B at Angle Indicated by Pointer. Molten aluminum flows from holding furnace through pouring trough T and into shallow molds M. As the mold bottoms are lowered slowly into the casting pit, water spray cools the three descending ingots from all sides. After pouring, trough is swung clockwise over heaters H, to keep it warm for the next use

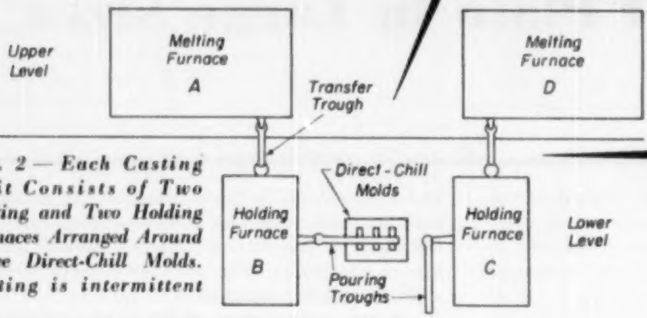


Fig. 2 — Each Casting Unit Consists of Two Melting and Two Holding Furnaces Arranged Around Three Direct-Chill Molds. Casting is intermittent

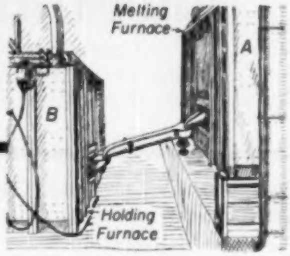
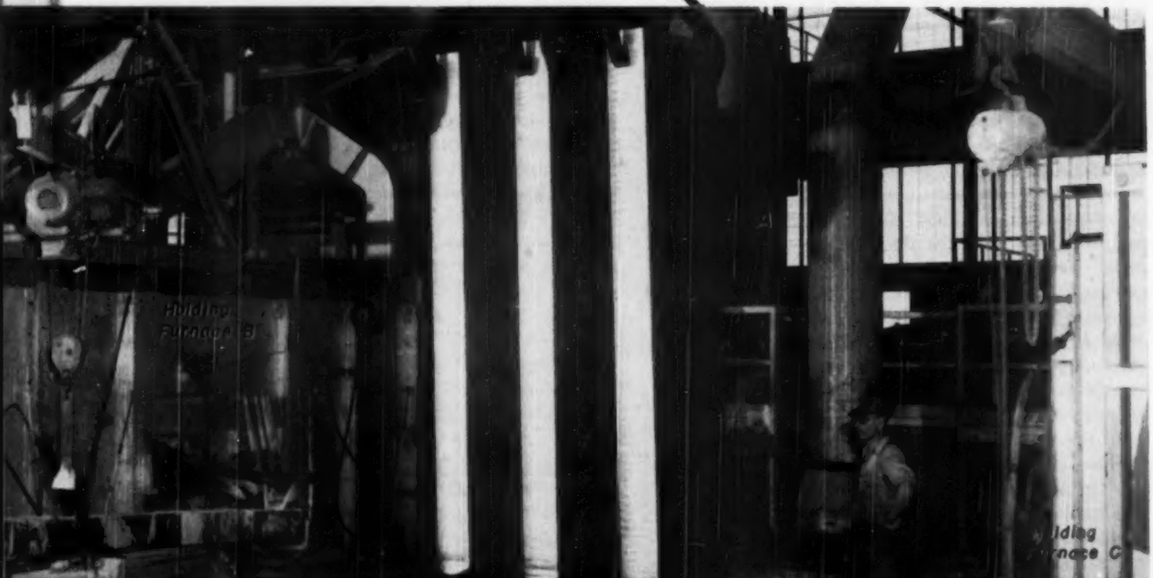


Fig. 3 — Metal Passes From Melting Furnace on Upper Level to Holding Furnace on Lower Level by Gravity Flow Through Interconnecting Trough

Fig. 5 (Below) — Direct-Chill Ingots Being Withdrawn From Pit. Holding furnaces B and C are shown at left and right, melting furnace A behind



1400° F. In order to shorten the cycle in the melting furnace and to provide a quiet, properly treated bath from which to withdraw the aluminum into the mold, metal is transferred from the melting furnace to a separate holding furnace after stirring or fluxing. Each holding furnace (15-ton capacity) is about 3 ft. lower than its partner melting furnace; the metal simply runs by gravity from the upper to the lower hearth, through an open trough, as indicated in Fig. 3.

In the holding furnace, temperature is closely controlled (±20° F.) at about 50° F. below that in the melting furnace. In addition to being brought to proper pouring temperature, the metal bath is degassed with aluminum chloride in the holding furnace and is left quiet for perhaps 20 min., to permit any remaining impurities either to settle or rise. Then the metal is ready to be withdrawn for casting.

Continuous and semicontinuous casting are by no means new in the aluminum industry. W. T. Ennor's patent on the direct-chill process is dated Nov. 3, 1942, and Alcoa had more than 60 of these casting units in operation by 1944. At Davenport Works the shallow molds are rectangular in cross section, either 12 x 36 or 12 x 48 in. Metal from the holding furnace flows through a refractory-lined runner and enters three molds simultaneously, as indicated in Fig. 4. Temperature in the upper part of the molds is about 40° F. lower than in the holding hearth. As soon as a shell of metal has solidified around the bottom of each mold, the bottoms start their descent into the pit below. The hydraulic platform drops at a rate of 3 to 5 in. per min., depending on the alloy being cast, and as the growing ingots descend, they are sprayed from all sides with water to complete the solidification.

Ingots are usually 136 in. long, which means that the total time for each pour is between 25 and 45 min. at the usual rates of lowering. The larger ingots (12 x 48 in. cross section), shown in Fig. 5, weigh about 7800 lb. each, or a total of nearly 12 tons in the three ingots from a single cast. Thus, with the two pairs of furnaces alternately supplying liquid metal to the molds and with the greatest rate of ingot descent, a theoretical maximum of about 25 tons of metal would be cast into each mold in an hour, or 125 tons per hr. if all five casting units were operating continuously. Actually, the time required for withdrawing the ingots and making preparations for pouring reduces this rate to about 30 tons per hr. maximum.

Scalping and Preheating — Ingots made by the direct-chill process have excellent hot working properties but the as-cast surfaces are liquated, with consequent roughness, as can be seen in Fig. 5. Before the ingots are rolled, this roughness is removed from each surface by a large Ingersoll milling machine having 52 carbide cutters.

The scalped ingots are then heated for rolling in gas-fired radiant-tube furnaces with forced air circulation. In this preheating operation, the metal is held at temperature (900 to 975° F. for most alloys) long enough to homogenize the structure considerably. For this operation ten soaking pits have been provided, each large enough to hold thirty 7000-lb. ingots. When production is continuous, metal goes to the hot mill within 5 min. of its withdrawal from the soaking pit.

Fig. 6 — All Ingots Rolled at Davenport Pass Through This 144-In. Reversing Hot Mill

144-In. Reversing Hot Mill — First unit on the hot line is the 144-in. reversing mill (Fig. 6) used for breaking down sheet ingots to 1-in. thickness and for rolling plate to final gage. Equipped with a 5000-hp. motor capable of delivering 10,000-hp. peaks, this mill reduces the standard ingots from 12 to 4 in. thickness in from 6 to 12 passes.

The 144-in. mill is considerably wider than necessary for the preliminary breakdown of ingots to be rolled on subsequent sheet mills; thus, its installation is a solid indication of Alcoa's confidence in the future demand for wide plates. In fact, not all of this demand is in the future. Enough 1⅛-in. plate to build 100 railway tank cars

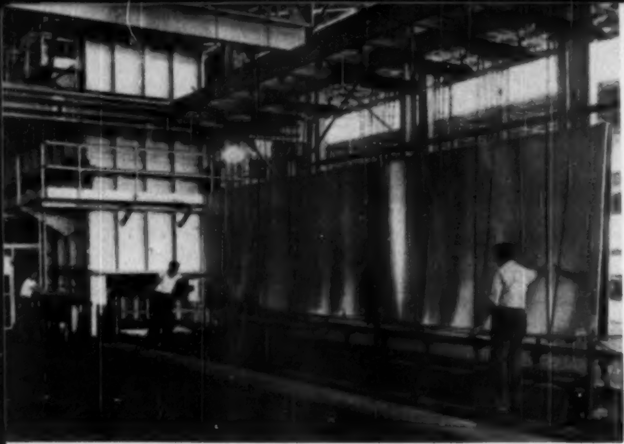


Fig. 7 — Only Three of These 1⅛-In. Plates Are Needed to Form the Cylinder for a Railway Tank Car. Heat treating furnace shown in background

was recently made in a single mill run (Fig. 7). Subsequently, another fabricator, General American Transportation Corp., formed these 92½ x 357-in. plates to a 120° arc of 42½-in. radius and welded three of them together lengthwise to produce the cylindrical shell of each tank car. Two 109-in. circles, sheared from similar 1⅛-in. plates, were dished to form the ends. Thus, only three longitudinal and two circumferential seams were required for each 32-ft. tank. The alloy was 61S (1% Mg, 0.6% Si, 0.25% Cu, 0.25% Cr), heat treated to the T6 condition in Swindell-Dressler furnaces like the one shown in the background of Fig. 7.

Another application for plate is the tapered sheet for airplane wings. The thin sheet used in conventional aircraft is inadequate for the wing coverings of modern jet-powered planes; ⅝-in. plate is required. The wide plate now available should result in a large decrease in the amount of riveting or other joining necessary in aircraft construction.

Five-Stand Continuous Hot Mill — The continuous hot strip mill (Fig. 8) is the most impressive piece of equipment at the Davenport Works. In passing through the five stands, a 1-in. slab is quickly reduced to an ⅛-in. strip, which may be either coiled or reeled at the exit end, depending on what operations are to follow. The tension reel on this mill is a new feature in the aluminum industry. The 100-in. width permits the rolling of coiled sheets 20 in. wider than was formerly possible.

Four-High Tandem Cold Mill — The four-high tandem mill (by Bliss) is the most modern piece of equipment in the cold rolling department. This 72-in. mill operates at 1500 ft. per min., about double the speed of other mills that are cold rolling aluminum. Thus, a 7000-lb. coil, 1000 ft. long and ⅛ in. thick, can be reduced to half that thickness (and double the length) in less than 90 sec. Three other mills complete the present facilities for cold rolling: 72-in., 4-high; 60-in., 2-high; 48-in., 2-high.

Plant Construction and Capacity — This new $75,000,000 plant was built in Davenport, Iowa, primarily because that location is close to the geographic center of all aluminum sales distribution. Also the plant is on the banks of the Mississippi, by which much of the aluminum pig will eventually be transported from the Point Comfort Works on the Texas Gulf Coast.

The Davenport Works not only makes aluminum sheet, but has made liberal use of it as a construction material. The plant itself is a showpiece in aluminum, displaying many novel applications of the metal in ways that the company hopes will be widely copied by industrial builders. More than 3000 tons of Alcoa's favorite metal went into the construction of this plant. From interior wall panels (colored light tan by a silk-screen "printing" process) to the woven wire fence outside, there is enough aluminum in use to emphasize that this plant is the "largest single application of aluminum in the history of the building trades".

The rated capacity of the Davenport rolling mills is 90,000 tons per year — enough, for example, to absorb the entire ingot output of both the Point Comfort, Texas, and Badin, N. C., reduction works. The Davenport Works, not yet in full production but operating at about 65,000 tons per year, can be converted to a war production capacity close to 150,000 tons annually in from three to six months. It is comforting to know that such a plant exists secure in the heart of rural America.

Fig. 8 — This Five-Stand, Four-High Continuous Strip Mill Rolls Larger Coils Than Any Mill in the Aluminum Industry

Correspondence

Sidney Gilchrist Thomas' Centenary

London, England

One hundred years ago, on April 16, 1850, was born in London, England, one Sidney Gilchrist Thomas, destined to become one of Britain's great metallurgists. His name in his home country is still somewhat eclipsed by that of Henry Bessemer; yet Thomas was the man who thought of and developed the basic bessemer process; his monument is now the enormous annual world output of basic steel. At the annual general meeting of the Iron & Steel Institute held in London in April, a special commemorative lecture was given by James Mitchell, of Stewarts and Lloyds Ltd., to mark the centenary.

The great achievement of Thomas was to solve the problem of dephosphorizing pig iron and steel in the converter process. His interest in this subject appears to have been aroused during a course of evening classes on metallurgy at the Birkbeck Institution when George Chaloner, the lecturer, stated that "the man who eliminated phosphorus in the bessemer converter would one day make his fortune". After studying analytical data, Thomas concluded that dephosphorization could be achieved by the substitution of a basic lining for the siliceous type then in use, and experimented with lime, and associated minerals such as magnesia and magnesian limestone. With the help of his cousin, Percy Carlyle Gilchrist, who was a chemist in steelworks at Cwm Avon, and later Blaenavon, South Wales, Thomas tested his theories on a small practical scale.

National Portrait Gallery, London (Artist Unknown)

Sidney Gilchrist Thomas
1850-1885

He was a business-like man and expended much time on delving into patent records to protect himself. Andrew Carnegie bought patent rights on behalf of his firm in America for $250,000, which, at present writing, would seem to have been a bargain for Carnegie. Up to the end of his short life, Thomas continued to take an interest in further developing his process, and made himself a rich man before his untimely death, due to lung trouble, when he was only 35. He directed that the financial rewards from his patents should, after his death, be applied for the improvement of the conditions of his fellow men.

Tom Bishop

Metallurgy in Spain

Syracuse, N. Y.

In a recent 12-day tour of Spain I was able, thanks to air transport, to visit several friends with whom I was associated some 15 years ago. My general impression may be reported in those words Queen Victoria wrote in 1837: "Affairs in Spain are very depressing." Nevertheless, my talks with the younger Spanish metallurgists and engineers in several lines of activity raised my hopes for the future.

Owing to the dim view taken by most governments toward the Franco regime and the general practices of currency control and international trade restrictions, it has been necessary for Spain to be practically self-sufficient in its internal economy. Spain's present annual production of steel is 730,000 tons (1949) — two million certainly could be used. There are several producers of pig iron and steel, but only one integrated mill — ore to nails — La Nueva Montana y Quijano, at Santander on the northern coast. Pig iron is produced in a 100-ton blast furnace; steel in two small bessemers and four 20-ton openhearths. Available scrap looks to be of exceedingly poor quality. Some pig iron is cast direct, one important product being rotary-cast pipe, up to 18-in. diameter.

Steel is cast in small ingots and rolled in an ancient hand mill into small merchant shapes and wire bar. This firm's wire mill and cable factory produce a diversified list and are of much importance to the Spanish economy, especially the fishing industry. One small electric-arc furnace and one induction furnace operate intermittently (because of power shortage) making ferro-alloys, alloy steels and toolsteels.

Self sufficiency in Spain must extend even to the manufacture of scientific instruments. I observed at the Instituto Leonardo Torres Quevedo in Madrid the following equipment under construction: polishing table, X-ray diffraction camera, pH meter, vacuum pump, hardness tester. At the University of Madrid, Professor E. Jimeno ● has installed, despite extraordinary difficulties, an exceedingly good metallurgical and metallographical laboratory, busy with instructional work — but also available for industrial research projects.

Space does not permit any detail of the metallurgical activities and production in Spain. It can be classed as small in all senses of the word. For example, a Barcelona "plant" for electroplating chromium occupies the basement of a residence. Industrialists and technical men everywhere are eager to learn and improve their techniques. They believe that the problems met in their neighboring countries are more in the scale of their own, and imagine *everything* in the United States to be huge.

The urge to improve, however, is evidenced by the formation of the Iron and Steel Institute of Spain, with membership of 800 industrialists and engineers. Its activities, so far, are principally the translation of foreign technical articles and their circulation, the organization of conferences and discussions (often led by foreign experts) and an appraisal of Spain's ferrous resources and needs.

F. R. Morral
Department of Materials Engineering
Syracuse University

American and Swedish Spring Wire

Turin, Italy

Swedish steel is justly regarded to be of high quality, and has been widely favored for such important uses as valve springs for internal combustion engines. American manufacturers have also produced quality material for exacting uses.

A.S.T.M. Specification A230-47 covers the requirements, and American mills have had no difficulty in meeting them. In Italy there is rather sharp competition between sellers of American and Swedish wire, and the word "quality" is often used by the salesmen. To get some facts on this matter I have tested a large number of springs made of oil-tempered carbon steel wire imported recently from Sweden and the United States. Mechanical tests and chemical analysis are as follows:

	Swedish	American
Tensile strength	244,000 psi.	217,280 psi.
Alternate torsions to 180°	192	398
Rockwell hardness	C-43 to 44	C-44 to 45
Analysis: C	0.62%	0.66%
Mn	0.50	0.77
Si	0.14	0.22
P	0.026	0.018
S	0.016	0.013

There was some difference in the microstructure, when examined at 100 diameters, the Swedish being much more pronouncedly banded in the longitudinal direction (after nital etch) clear to the surface. The surface layers of the American wire appeared free from banded structure. Neither wire showed any decarburization at the surface.

Springs were coiled of a 0.1695-in. diameter wire, blued 20 min. at 500° F. and shot-peened with intensity 0.011 on the Almen gage No. 2. The springs had 0.916-in. pitch diameter, six active coils, free length of 1.86 in. and Wahl factor $K = 1.28$. These springs were placed in a fatigue machine and runs made with minimum stress of 35,800 psi. and maximum stress of 95,200 psi.; testing speed was 1500 r.p.m.

In a representative series of tests, six springs of American wire each endured 11,722,000 reversals of stress, and were unbroken when the test was stopped. In a parallel series of tests on springs of Swedish wire, five remained unbroken, one broke after 6,382,000 reversals. No defect could be discovered in the last-mentioned spring.

It is my opinion, therefore, that at present American wire for valve springs (quality, oil-tempered carbon steel wire) is comparable in quality and fatigue resisting properties with the better Swedish wire.

Alberto Oreffice
Chief Engineer
Steel Department, Fiat Co.

Details of Jernstedt's "PR" process, capable of making electroplates rapidly of any thickness and of high density, good adherence, and so smooth as to require no buffing or polishing

Periodic Reverse-Current Electroplating

A PROCESS of electroplating has been devised, patented by George W. Jernstedt, of the Westinghouse Electric Corp., by which the plated deposit shows superior physical properties and freedom from flaws such as porosity. In this process, the plating current is reversed briefly at short intervals, thereby preferentially removing what may be unsound and inferior metal deposited in the previous plating period and building up many microscopically thin layers of sound metal to form a deposit of higher density and homogeneity than is possible by conventional continuous-current methods. The surface of the deposit is smoothed progressively with each succeeding increment. It is brightened by the current reversal, and buffing or polishing, therefore, can be reduced or even eliminated. The net deposit adheres more tightly; heavy thicknesses of plate, for example ¼ in., can be produced without surface flaws. Finally, the speed of plating can be increased without sacrifice of quality.

In electroplating with any solution, the limit of current density is reached when the electrolyte adjacent to the cathode becomes sufficiently depleted in metal ions. Thereafter, part of the water in the electrolyte is decomposed and hydrogen forms on the surface of the work as a blanket, thereby diminishing the rate of metal deposition. Plating is therefore conducted at such a rate as to prevent or minimize this action. By the use of periodic reverse current, enough metal ions are returned to the electrolyte adjacent to the cathode during periods of current reversal so that the depletion is negligible, even with current densities (and consequently, over-all speeds of plating) increased many fold.

Theoretically, due to the reverse or deplating portion of the cycle, the over-all electrical efficiency is reduced as compared with continuous direct-current plating. For example, in a cycle of 5-sec. plating-time current and 1-sec. reverse current, totaling 6 sec., the net metal deposited amounts to that applied in 4 sec. continuous direct-current plating time, or 66⅔%. However, a number of compensating factors reduce this apparent loss. The plating part of the cycle in some solutions appears to operate at higher efficiencies than in continuous-current plating. Reduction in metal depletion also expedites the plating part of the cycle so that the over-all plating efficiency is improved. Nevertheless, the most important element in the speed of periodic reverse-current plating is the higher current density applied.

The quality of periodic reverse plating, even at high speeds, is usually better than the best continuous direct-current plating. As an example, 0.016 in. of copper has been deposited by conventional practice on meter magnets in potassium copper cyanide barrel plating, in from 7 to 10 hr.

By Adolph Bregman
Consulting Editor for Metal Progress
Consulting Engineer
New York City

By still plating, this time may be cut to some 5 hr., but the plate is nodular and pebbly. With reverse current, a smooth, dense deposit was produced in less than 4 hr.

The process is simple, requiring no bath control other than that usually employed. Cycles in which the time of plating is three to five times the time of reversed current have been found to be most satisfactory; for example, the cycle may be 5 sec. direct to 1 sec. reverse or 30 sec. direct to 6 sec. reverse. Cycles of 15:3 or 15:5 sec. are most generally employed.

Equipment Required

Up to the present time, three types of equipment have been proposed to effect current reversal. For one, it has been suggested that two rectifiers may be used, one for plating and one for deplating. Under this system, certain electrical difficulties make it necessary to employ two sets of anodes and, in practice, this greatly reduces the anode efficiency and limits the current density at which a given bath may be operated.

A second method involves generator field reversal. This method is practicable but also has a minor disadvantage in that the lag in the current-time curve characteristic of this type of reversal results in a loss in efficiency. A recent trend is discernible, however, toward the use of generator field reversal because of the low cost and ease of making this type of installation.

The third method of current reversal depends simply upon inserting polarity-reversing contactors between rheostat and tank, these being actuated by a suitable timer. As the result, the equipment listed below has been developed and is available.

1. Controller, 50 amp., consisting of direct-current coil-actuated contactors controlled by an adjustable electronic timer, the limits being 1 to 25 sec. cathodic and ½ to 5 sec. reverse.

2. Contactors, 800 amp., consisting of a unique solenoid-type movement making for very little lag in the time-current curve. Used in conjunction with No. 1, which interrupts the 125-volt, 3-amp. current drawn by the coil, the same time-cycle range is possible as described for No. 1.

3. Contactors, up to 3000 amp., consisting of two sets of coil-actuated contactors provided with arc shoes to increase the life of the silver alloy contacts. Used in conjunction with No. 1, this heavy-duty unit is said to give long service with minimum upkeep cost.

Obviously, this type of equipment must be built to withstand many million operations in order to be serviceable.

Operating Methods

Copper Plating Baths — The periodic reverse (PR) process operates satisfactorily with ordinary copper cyanide baths to give smooth, semibright deposits at increased current densities. However, it is more widely used with high-speed copper solutions, such as the Rochelle salt type, and also in a variety of proprietary baths using addition agents.

For Rochelle copper cyanide, the following bath has been recommended:

Copper	4 to 4.5 oz. per gal.
Sodium hydroxide	2 to 2.5
Free sodium cyanide	1 to 1.5
Rochelle salt	5
Current density	75 A.S.F.
Voltage	3
Temperature	140° F.
Anodes (bagged)	Electrolytic copper

This bath is said to yield full-bright deposits using a 15:3 sec. cycle. Continuous filtration and solution agitation are recommended.

Proprietary organic brighteners may be used with this bath, but it has been found that the use of such additions can be reduced to $\frac{1}{10}$ the usual amount or even eliminated. One inorganic brightener, called "Wes-X" has been developed by Jernstedt, for the purpose of refining the grain size and to assure bright deposits. With this addition agent, the following solution composition is recommended:

Copper as metal	6 oz. per gal.
Free sodium cyanide	1
Sodium hydroxide	2
Rochelle salt	5
Wes-X	0.8
Current density	60 to 120 A.S.F.
Voltage	2 to 3
Temperature	180° F.

Some of the best results with the PR process have been obtained with the use of a high-speed copper bath free from all organic addition agents, made up as follows:

Copper	7.5 to 9.0 oz. per gal.
Potassium hydroxide	4.0 to 6.0
Free potassium cyanide	0.8 to 1.5
Wes-X	0.8 to 1.5
Current density	60 to 100 A.S.F.
Voltage	2 to 3
Temperature	17 to 190° F.
Anodes	Electrolytic copper

Sodium salts may also be used in the above bath, and when they are the copper content should be 11 to 12 oz. per gal. and the sodium hydroxide 4.5 oz. per gal. The potassium bath is recommended. This bath may be operated the same as any high-speed copper bath. *(Continued on p. 261)*

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Tensile Properties of Arc-Cast Molybdenum

By Climax Molybdenum Co.

Tensile Properties and Hardness at Room Temperature

Annealing Temperature	Yield Point, Psi.	Tensile Strength, Psi.	Elongation	Reduction of Area	V.P.N.
		Arc-Cast, Hot Rolled to ½-In. Diameter Bars			
Hot Rolled	99,800	100,100	32%	60.9%	255
1700° F.	—	91,700	39	59.2	—
1900	84,700	90,600	41	65.7	—
2100	54,100	73,100	53	64.2	187
2200	50,100	73,600	55	55.6	187

Test specimens, ¼-in. diameter; gage length, 1 in.; strain rate, 60% per hr.

Directional Properties at Room Temperature
(Arc-Cast, Hot Rolled, Annealed)

No.*	Direction†	Yield Point, Psi.	Tensile Strength, Psi.	Elongation	180° Bend Over T‡	
					Cold	Hot
		0.030-In. Sheet, Annealed at 1850° F.				
SR-2	0	101,700	106,300	22	OK	
	90°	116,300	117,200	18	NG	
	45°				OK	
CR-2	0	102,800	107,800	22	OK	
	90°	109,600	110,900	14	NG	OK
	45°				OK	
		0.020-In. Sheet, Annealed at 1800° F.				
SR-1	0	99,500	105,400	12	NG	OK
	90°	112,900	115,400	8	NG	OK
	45°				NG	OK
CR-1	0	104,700	111,400	14	OK	OK
	90°	121,600	122,000	8	NG	OK
	45°				NG	OK
SR-2	0	103,600	109,000	11	NG	OK
	90°	114,900	117,300	13	NG	OK
	45°				NG	OK
CR-2	0	108,900	114,100	14	OK	OK
	90°	123,500	125,100	12	NG	OK
	45°				NG	OK
		0.013-In. Sheet, Annealed at 1800° F.				
SR-1	0	102,400	116,500	14	OK	
	90°	116,000	118,400	8	NG	OK
	45°				OK	
CR-1	0	106,400	110,100	11	OK	
	90°	107,000	108,500	10	NG	OK
	45°				OK	
SR-2	0	108,300	112,700	14	OK	
	90°		124,000		NG	OK
CR-2	0	107,000	112,500	10	OK	
	90°	120,000	121,000		NG	OK

*SR, straight rolled; CR, cross rolled. †Direction of the test bar in relation to final rolling. ‡Thickness.

Elastic Constants at Elevated Temperatures*

Testing Temperature	Young's Modulus, Million Psi.	Modulus of Rigidity, Million Psi.	Poisson's Ratio	Young's Modulus† (Koster)
		Metal From Powder Process		
80° F.	45.2	17.3	0.307	47.75
250	44.9	17.2	0.308	47.30
400	44.2	16.9	0.305	46.75
500	44.2	16.9	0.305	46.40
600	43.7	16.8	0.307	46.0
700	43.5	16.7	0.305	45.6
800	43.2	16.5	0.307	45.1
900	42.9	16.3	0.307	44.6
1100	42.0	16.0	0.312	43.8
		Arc-Cast, Hot Rolled to ½-In. Diameter Bars		
80	46.0	17.4	0.324	
280	44.7	16.9	0.330	
500	43.2	16.4	0.319	
725	42.7	16.3	0.317	
1175	41.0	15.6	0.314	
1400	39.9	15.1	0.321	
1600	39.9	15.1	0.321	

*The possible error is about 2% for the moduli and 4% for Poisson's ratio. †Dynamic modulus, measured by the tuning-fork method.

Directional Properties of Cold Rolled Sheet at Room Temperature
(Arc-Cast, Cold Rolled From 0.052 to 0.020 In.)

Annealing Temperature	Yield Point	Tensile Strength	Elongation
	Longitudinal		
Cold Rolled	151,800 psi.	154,300 psi.	5%
1600° F.	126,500	131,500	12
1700	121,500	124,500	10
1800	111,000	117,300	13
1900	98,000	105,500	17
2000	74,400	88,800	29
2100	73,100	91,300	28
2200	75,500	90,600	26
2300	81,800	88,400	26
2400	75,400	78,800	39
	Transverse		
1600° F.	130,200	132,100	3%
1700	120,900	120,900	2
1800	—	123,400	2
1900	113,700	114,700	8
2000	81,200	93,500	17
2100	86,700	91,500	16
2200	82,800	91,100	17
2300	55,000	89,400	16
2400	76,800	83,200	22

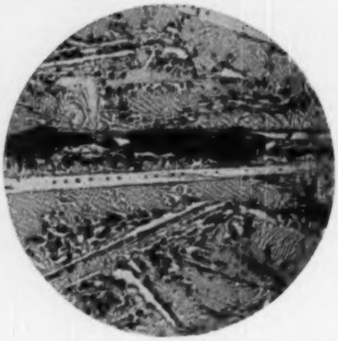
Tested in 1-in. gage length, ½ in. wide.

Tensile Properties at Elevated Temperatures

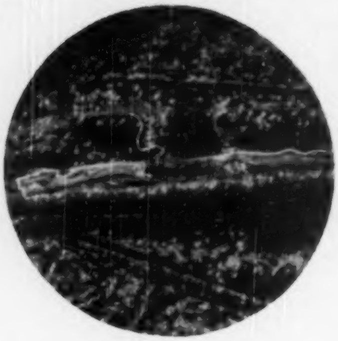
Testing Temperature	Condition	Tensile Strength, Psi.	0.2% Yield Strength	Proportional Limit	Elongation in 2 In.	Reduction of Area
		Arc Cast, Hot Rolled to ⅝-In. Diameter Bars				
80° F.	As rolled	95,140	—	—	3%	2%
	Stress relieved	91,000	84,850	—	10	9
	Recrystallized	67,600	63,500	—	46	36
1600	As rolled	61,400	50,100	26,000	18	72
	Stress relieved	50,600	44,500	21,500	22	81
	Recrystallized	34,400	11,600	3,500	46	84
1800	As rolled	49,900	40,500	23,000	19	81
	Stress relieved	40,500	35,600	22,500	32	81
	Recrystallized	29,000	10,500	5,700	49	75
1950	As rolled	38,000	31,600	24,000	29	83
	Stress relieved	31,400	22,800	16,500	36	84
	Recrystallized	21,500	8,550	4,100	35	52

NOTES: The test bars, which were 0.505-in. diameter, were sprayed with aluminum to prevent oxidation while testing at elevated temperatures. Except where noted, the test bars were brought to temperature with the furnace and held for 20 min. before testing. They were loaded at the rate of 1000 psi. per min. The hot rolled material had been annealed at 1800° F. for 20 min. and then machine straightened while warm. The best stress relieving temperature, on the basis of combined tensile strength and ductility, was 1850° F. A satisfactory temperature to recrystallize the as-rolled material was 2250° F.

See it! Photograph it!... 4 Ways



1
BRIGHT FIELD



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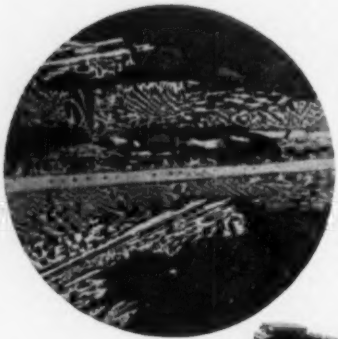
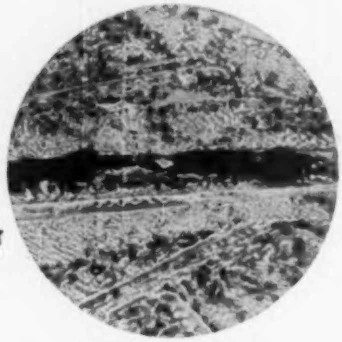
DARK FIELD

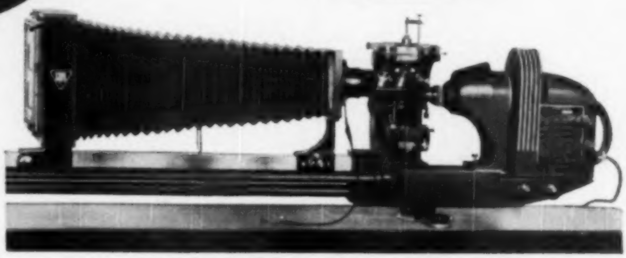


3
POLARIZED LIGHT



4
PHASE CONTRAST

Photomicrographs of an unetched 15% manganese cast iron sample



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An 18-8 valve stem, after 15 years of use in equipment making liquid oxygen, transformed partially to martensite under the influence of service strains at low temperature (near —300° F.). This prompted a broader investigation of the effect of low-temperature straining on the impact strength of 18-8. The results showed that strains of the magnitude encountered in service can have only a minor effect.

Effect of Cold Work at Low Temperature on Austenitic 18-8

AUSTENITIC 18-8 chromium-nickel steels are used extensively in industry for service at normal and elevated temperatures. They are also suitable for applications involving shock and high stresses at *low* temperatures, and usage of the steels for this purpose has increased tremendously in recent years. They are selected in preference to pearlitic and ferritic steels because they retain their resistance to shock at much lower temperatures.

Much has been written about the low-temperature mechanical properties of 18-8 steels in both the annealed and cold worked condition. The tensile strength in the annealed condition rises from 90,000 psi. at room temperature to 225,000 psi. at −295° F., and the yield strength increases from 35,000 to about 85,000 psi. This strengthening effect is not accompanied by any significant loss of ductility or toughness. The data further show that the steels are structurally stable at low temperatures as long as they are not plastically strained.

While constitutional studies reveal that the austenitic 18-8 steels are thermodynamically unstable, the steels are extremely sluggish and, in practice, the structure stable at elevated temperatures persists unmodified at subzero temperature. However, cold work causes the metastable austenitic phase to transform partially to the stable ferrite phase. The transformation has a profound influence on the mechanical and physical properties of the steel, both at elevated and at low temperatures, increasing the strength, hardness, and magnetic permeability of the steel and lowering its ductility and shock resistance.

The extent to which the transformation proceeds depends on several factors — the composition of the steel, temperature of cold work, amount of cold work and the rate of deformation. Although a complete understanding of the transformation is still lacking, it has many of the characteristics of the martensite reaction observed in ordinary steel, several pure metals and various nonferrous alloys.

Structural Stability of Austenitic 18-8 Steel at Liquid Oxygen Temperature

The marked susceptibility of the 18-8 steels to work hardening during cold working is due to their tendency to transform partially to martensite, which augments the normal gain in strength resulting from the mechanical deformation of the steel. The wide range of mechanical properties which these steels can develop by cold working is due to this unique combination of transformation and normal strain hardening.

By W. O. Binder
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To determine whether transformation occurred in service under conditions where some plastic strain was possible, the Union Carbide and Carbon Research Laboratories, Inc., examined a valve stem made of Type 303 stainless steel (17.08% Cr, 9.03% Ni, 0.077% C, 0.095% S, 0.57% Mn, 0.42% Si) that had been in liquid oxygen service for a period of 15 years.

Before cutting the piece into samples for metallographic and impact tests, the valve stem was submitted to a rough magnetic test using a small Alnico permanent magnet.

As shown in Fig. 1, the portion of the stem nearest the disk end strongly attracted the magnet; however, the magnetic susceptibility of the stem diminished markedly a short distance away from this point. The metal opposite the disk end was found to be substantially nonmagnetic. The differences in magnetism were attributed to different conditions of strain in service. The micrographs in Fig. 1 reveal that where the steel is magnetic, martensite is present and where the steel is nonmagnetic the austenite is untransformed. It is a matter of extreme interest to find that the steel showed no evidence of transformation except where it had been subject to strain, even though the steel had been in liquid oxygen service for a period of 15 years.

Since a portion of the valve stem had transformed, it was decided to determine whether the impact resistance of the steel had been seriously decreased. Two keyhole-notch Charpy specimens from the nonmagnetic portion of the stem and one from the transformed portion were machined. One of the specimens representing the untransformed metal was tested at room temperature, and the other was tested at −295° F. The specimen of transformed metal was tested at −295° F. Results are as follows:

Location of Impact Specimen in Valve Stem	Room Temp.	−295° F.
End away from disk (nonmagnetic)	33 ft-lb.	25 ft-lb.
Threaded portion (magnetic)	—	21

The toughness of the nonmagnetic portion of the valve stem is of a relatively high order at both room temperature and −295° F., and that of the transformed portion is only 4 ft-lb. lower. The transformation had little adverse influence on the low-temperature toughness of the steel. The high toughness of the steel after partial transformation is attributed to the fact that the low-carbon martensite resulting from the transformation is more ductile than the high-carbon martensite obtained in the ordinary heat treating steels of higher carbon content.

Effect of Strain at Low Temperatures on the Stability of Types 304 and 347 Steel

Although our examination of the valve stem indicated that serious loss of toughness at low temperatures was quite unlikely in service, it was decided to investigate the effect of strain at low temperatures on the transformation and impact properties of austenitic 18-8 steel in greater detail so as to obtain a more complete understanding of their low-temperature transformation characteristics. Of particular interest was information on Types 304 and 347 steels in the form of heavy

This Liquid-Oxygen Producing Unit Requires Many Parts of Stainless Steel for Low-Temperature Service

plate and after welding, as these steels are used very extensively for fabricating low-temperature equipment.

In conducting this study, it was necessary to make measurements of the effect of strain and the temperature of straining on the progress of the transformation and the shock resistance of the steels. The extent of transformation was determined by hardness measurements, magnetic balance tests, and to a limited extent by X-ray diffraction studies.

Materials and Test Procedures — The materials tested were in the form of rolled plate ⅞ in. thick, and prior to testing the plates were held for 1 hr. at 1900 to 1965° F. and water quenched. The chemical compositions of the steels and welding electrodes are given in Table I. Each plate was prepared for welding by machining a groove having a 20° included angle with a ¼-in. bottom radius and a $\frac{1}{16}$-in. nose.

Straining was carried out on threaded-end specimens having a 0.625-in. diameter and a 4-in. gage length that were machined normal to the rolling direction of the plate and the axis of the weld. Strain values of 0.5% were measured with a dial indicator mounted on extension arms clamped to the reduced section. Large values of strain were measured by means of extension wires soldered to the shoulders of the specimen. To insure temperature uniformity, the specimens were held 30 min. at the test temperature before straining, and to allow for attainment of equilibrium after straining, the load imparting the desired strain was sustained for 30 min.

Double-notched Izod specimens were machined from the reduced section of the tensile specimens, and in the welded specimens, one of the notches was located in the top of the weld. Unless otherwise noted, all impact tests were at −295° F.

Type 304 Steel — To obtain a comprehensive picture of the influence of strain and temperature of straining on the transformation process in Type 304 steel, a series of tests was conducted on specimens strained the following amounts at room temperature, −110° F. and −320° F.: *(a)* To a value corresponding to a stress of 15,000 psi., which is the allowable design stress for this type of steel, *(b)* to 0.5% total elongation, which is approximately the percentage strain when the steel is stressed to its yield strength measured at 0.2% offset, *(c)* to 10% total elongation, and *(d)* to 20% total elongation.

The results of these tests are summarized in Fig. 2. Up to 20% straining at room temperature has only a negligible effect on the magnetic characteristics, hardness and impact strength of the steel, but straining in excess of 4% at −110 or −320° F. causes the steel to transform to martensite with a large increase in magnetic pull and hardness, and a significant loss of subzero impact toughness. However, the impact toughness of the steel is not seriously reduced by strains up to the yield strength of the steel, and to reduce the impact

Fig. 1 — Liquid Oxygen Withdrawal Valve Stem (Half Size). Note the strong magnetic susceptibility at the disk end and lack of magnetic attraction at the opposite end. Micrographs show structures at locations indicated

value below the minimum accepted by the A.S.M.E. Boiler Code, a total strain of at least 20% at −320° F. is required.

Some insight as to the extent of the transformation due to cold straining was gained by examining the microstructures and X-ray diffraction patterns of the specimens. The X-ray data summarized in Table II show that room temperature straining fails to change the diffraction pattern of the steel. However, a small amount of transformation is evident in the metallographic structure (Fig. 3). Straining a total of about 20% at −110° F., on the other hand, produced about 30% ferrite and at −320° F. about 45% ferrite. The metallographic structure of the latter samples is included in Fig. 3.

Of considerable interest is the fact that the specimens strained 10 and 20% at subzero temperatures exhibited, besides austenite and ferrite, a hexagonal phase having the same interatomic spacings as the low-temperature form of cobalt. It was estimated, from the intensity of the diffraction lines, that approximately 10% of the austenite had transformed to the hexagonal phase. No increase in the amount of this phase occurred as the total strain was increased. The influence of this phase on the properties of the steel is unknown.

The formation of the hexagonal phase seems to be affected by the method of cold working. Only traces of the phase have been observed in samples of 17-7 and 18-8 steel reduced 18% in thickness at −110° F. by cold rolling, and it has not been observed in austenitic chromium-nickel steels hardenable by heat treatment.

Table I — Mill Analyses of Plates and Welding Electrodes

Type	Cr	Ni	Mn	Si	C	Cb	Form
304	18.19	9.12	1.35	0.59	0.056	—	3/8-In. Plate
347	18.56	11.02	1.43	0.70	0.056	0.72	3/8-In. Plate
310	26.60	21.24	1.72	0.38	0.13	—	3/16-In. Rod
347	19.76	10.09	1.69	0.40	0.05	1.10	3/16-In. Rod

Type 347 Steel — Figure 4 indicates that in many respects the transformation characteristics of Type 347 steel are quite similar to those of the Type 304 steel. At room temperature, Type 347 transforms slightly when strained up to about 10%, but when strained at −320° F., there is a much sharper decrease in toughness, and an increase in hardness and magnetic pull indicative of greater transformation. Microstructures of typical samples are shown in Fig. 5.

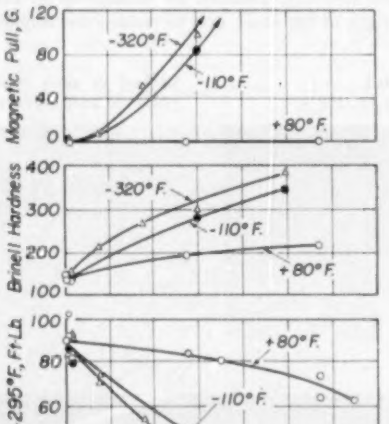


Fig. 2 — Effects of Straining Annealed Type 304 Steel. Straining temperatures are indicated on the curves

Strained at +80° F. Strained at −110° F. Strained at −320° F.

12% Strain

20% Strain

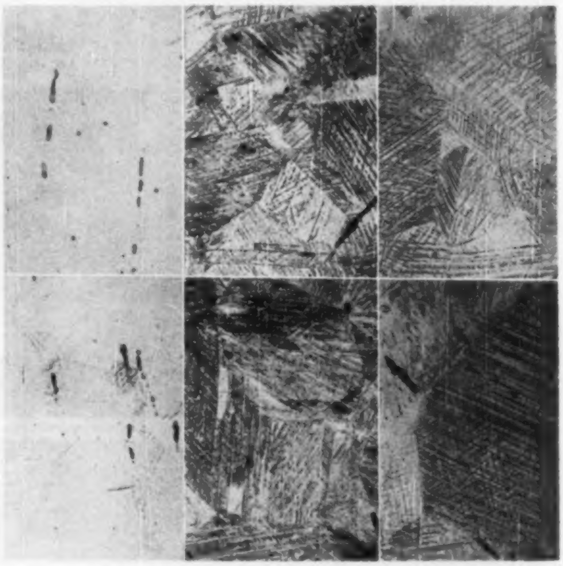


Fig. 3 — Annealed 304 Plate After Straining at Different Temperatures. Etched in 45% HCl, 5% HNO_3, 50% H_2O; 250×

The practical indications from the tests on the annealed Type 347 plate are similar to those of the Type 304 steel; although considerable loss in subzero impact toughness is obtained through large amounts of strain at −320° F., the effects of small amounts of strain, such as 2%, are minor.

Effect of Welding and Stress Relieving — To determine the transformation characteristics of weld metal, a series of similar tests was made on welded specimens. Type 304 steel was welded manually with coated electrodes of Type 310 steel. This electrode was chosen because experience has shown it to possess consistently good low-temperature impact.

The Type 347 steel was welded with coated electrodes of Type 347 steel. In straining the weldment, it was found that the weld metal deformed less than the adjacent plate metal, due to the greater strength of the weld metal. Because of this difference, the amount of strain in the weld metal had to be limited to about 6% to avoid experimental difficulties connected with the design of the specimen.

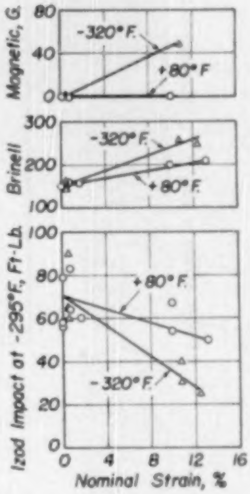


Fig. 4 — Effects of Straining Annealed 347 Steel. Straining temperatures indicated on curves

Table III, on the next page, summarizes the results of tests on Type 310 steel weld metal; it has good impact toughness even though strained 5 to 6% at −320° F. The loss of impact toughness due to straining is gradual and is more typical of austenite work hardening than martensite formation. The micrographs in Fig. 6 do not reveal significant amounts of transformation in the strained specimens.

Table II — Effect of Strain at Different Temperatures on the Structure of Type 304 Steel

Strain	Temp. Strain	Magnetic Pull	Rockwell	X-Ray Structure
23%	+80° F.	0.37 g.	C-19	100% Austenite
20	−110	>200	C-37	60% Austenite 30% Ferrite 10% Hexagonal
to 15,000 psi.	−320	0.07	B-72	100% Austenite
12%	−320	99	C-32	65% Austenite 25% Ferrite 10% Hexagonal
20	−320	>200	C-41	45% Austenite 45% Ferrite 10% Hexagonal

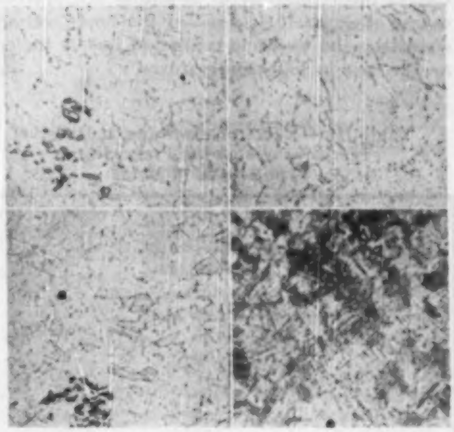


Fig. 5 — Structure of Annealed Type 347 Plate After Straining at Different Temperatures. Etched in 45% HCl, 5% HNO_3, 50% H_2O; 250×

Stress relieving at 1300° F. decreased the toughness of Type 310 weld metal to 20 ft-lb. when strained 2%, indicating that this treatment should be avoided when optimum toughness in the weld is desired. If it is necessary to remove welding stresses, these tests indicate that the weld should be heated to 1900° F., a treatment that does not lower the toughness of the weld.

As shown in Table IV, unless the straining is of the order of 10% or more, the toughness of Type 304 steel plate metal is not seriously affected by stress relieving at 1300° F.

The impact strength of Type 347 weld metal, as shown in Table V, falls between 15 and 20 ft-lb., bordering on the minimum allowable toughness considered satisfactory in service. However, in the as-welded condition, the toughness of the weld is not decreased appreciably by straining up to about 4%. Stress relieving, particularly at 1300° F., should be avoided, as it is detrimental to the toughness of the weld metal. Heat treatment at 1900° F.

seems more satisfactory for the elimination of welding stresses in this type of steel than either 1300 or 1600° F. Typical microstructures of the Type 347 welds are presented in Fig. 7.

Table VI summarizes the data showing effects of straining on the low-temperature impact strength of Type 347 steel plate metal after undergoing the same heat treatments applied to the weldments. Unless the conditions of straining are severe, in excess of 10 to 15%, none of the heat treatments embrittles the steel and renders it unsafe for engineering use at low temperatures.

Table III — Effect of Straining at Different Temperatures on the Properties of Type 310 Weld Metal

Strain in Weld	Straining Temperature	Izod Impact at −295° F.
	As Welded	
0	—	34 ft-lb.
to 15,000 psi.	+80° F.	51
0.09%	+80	47
5.0	+80	27
to 15,000 psi.	−110	42
to 15,000 psi.	−320	36
0.5%	−320	41
2.0	−320	35
6.0	−320	28
	2 Hr. at 1300° F., Air Cooled	
0	—	28
2.0	−320	20
	2 Hr. at 1900° F., Air Cooled	
0	—	46
2.0	−320	42

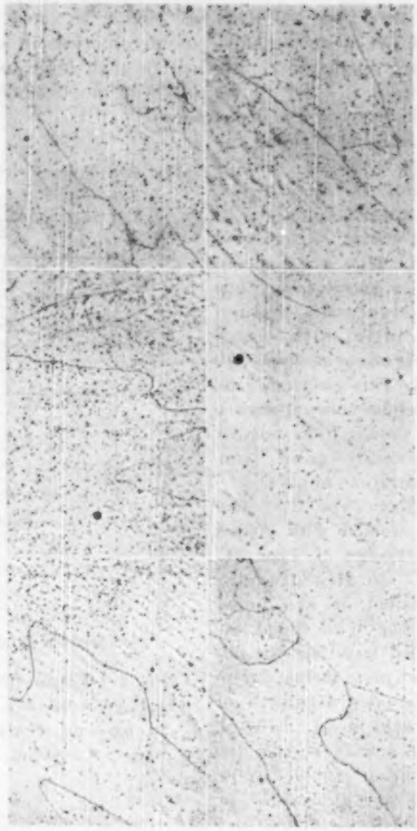


Fig. 6 — Microstructure of Type 310 Weld Metal After Straining at Different Temperatures in the As-Welded Condition. Samples etched in 45% HCl, 5% HNO_3, 50% H_2O; 250×

Summary

An austenitic 18-8 steel valve stem in liquid oxygen service for 15 years was examined to gain an insight into the structural behavior of this type of steel when exposed to low temperatures for an extended period of time. This examination showed that the portion of the stem subjected to maximum strain in service had transformed partially to martensite, whereas the less highly strained parts were substantially unaffected by the service conditions. Charpy impact tests made on both portions of the stem revealed little change in the untransformed section, and only a small decrease in subzero impact strength in the transformed section of the valve stem.

These results reveal that austenitic 18-8 steel is a structurally stable material at subzero temperatures — unless, as brought out by our subsequent studies, the metal had been critically strained.

Table IV — Effect of Straining on the Low-Temperature Impact Properties of Type 304 Steel

Strain in Plate	Straining Temperature	Izod Impact at −295° F.
	Annealed	
0	—	90 ft-lb.
11.0%	−320° F.	31
	2 Hr. at 1300° F., Air Cooled	
0	—	67
10.7	−320	16
	1 Hr. at 1900° F., Air Cooled	
0	—	93
10.7	−320	34

Table V — Effect of Straining at Different Temperatures on the Properties of Type 347 Weld Metal

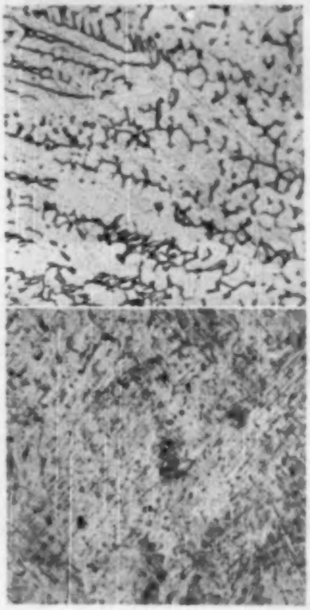
Strain	Strain Temp.	Izod at −295° F.
	As Welded	
0	—	15 ft-lb.
0.5%	+80° F.	17
2.0	+80	20
0.5	−320	20
4.0	−320	18
2 Hr. at 1300° F., Air Cooled		
0	—	9
4.0	−320	4
2 Hr. at 1600° F., Air Cooled		
0	—	15
6.0	−320	8
2 Hr. at 1900° F., Air Cooled		
0	—	55
6.0	−320	13

The complex behavior of the valve stem brought out the need for accurate information on the transformation characteristics of 18-8 Cr-Ni steel, and, therefore, a study of the effect of strain and straining temperature on the properties of Types 304 and 347 steels was carried out. This study has shown that strains in excess of yield strength loading (0.2% offset) are required to induce measurable amounts of transformation and that transformation due to 2% straining at low temperatures has only a minor effect on the subzero impact strength of the steels.

The latter information is important as it reveals that severe overstrain is required to produce a significant loss of toughness at subzero temperatures in these steels. Since excessive overstraining is seldom encountered in service, no trouble is anticipated due to loss of toughness in this manner. Furthermore, the enormous increase in strength which these steels undergo at low temperatures renders the possibility of serious overstraining extremely unlikely.

The investigation included also a study of the effects of subzero temperature straining on Types 310 and 347 steel weld metal in both the as-welded and

As-Welded Condition; 4% Strain at −320° F.



1 Hr. at 1900° F., Air Cooled; 6% Strain at −320° F.

Fig. 7 — Structure of Type 347 Weld Metal After Straining at −320° F. Etched in 45% HCl, 5% HNO_3, 50% H_2O; 250×

stress-relieved conditions. In the as-welded condition, Types 310 and 347 welds are quite resistant to transformation up to 2% strain. The Type 310 weld, after straining, maintains a subzero impact value in excess of 35 ft-lb., but the Type 347 weld has a considerably lower level of toughness — ranging from about 15 to 20 ft-lb.

Stress relieving at 1300 and 1600° F. is detrimental to the subzero toughness of Type 347 weld metal in the strained condition, as it lowers the toughness of the weld at −295° F. below the minimum accepted value. Type 310 weld metal is also detrimentally affected by stress relieving, and it loses 40 to 50% of its subzero impact strength when heated at 1300° F. and then strained 2% at −320° F. If it is necessary to remove welding stresses, heat treatment at 1900° F. appears more satisfactory than the lower temperatures, as it does not decrease the toughness of Type 310 weld metal and improves that of Type 347 weld metal.

Unless Type 304 or 347 steel is severely overstrained at subzero temperatures — a very unlikely condition — stress relieving at 1300 and 1600° F. does not lower the subzero toughness of these steels in the wrought condition.

It is clear from these results that balanced austenitic 18-8 steels possess a unique combination of strength, ductility and toughness which renders them eminently suitable for low-temperature service.

Table VI — Effect of Straining on the Low-Temperature Impact Properties of Type 347 Steel Plate

Strain	Strain Temp.	Izod at −295° F.
	Annealed	
0	—	56 to 79
12.4%	−320° F.	25 ft-lb.
2 Hr. at 1300° F., Air Cooled		
0	—	52
13.5	−320	24
1 Hr. at 1900° F., Air Cooled		
0	—	55
13.2	−320	25
2 Hr. at 1600° F., Air Cooled		
0	—	86
12.0	−320	29

Personal Mention

Massachusetts Institute of Technology has added to its staff, with rank of professor in the mechanical engineering department, **Egon Orowan**, well-known to theoretical metallurgists for his work on plastic flow, creep, and notch brittleness. Dr. Orowan was born in Hungary in 1902, educated in Germany, and went to England in 1937, where his researches into the mechanical properties of metals were done at Birmingham and Cambridge universities. He is a leading proponent of the theory that a crystal of metal contains many submicroscopic imperfections or dislocations — that is to say, regions where the atomic spacings lose their theoretical regularity — and such visual phenomena as slip, work hardening, aging and over-aging can be analyzed by a knowledge of the interatomic forces existing at such dislocations. He has extended these theoretical considerations in many publications on the more "practical" aspects, such as roll pressures and fracture of ship plate.

Aluminum Co. of America announces that **Robert T. Wood** has been appointed chief metallurgist of magnesium products for the company. Mr. Wood started with Alcoa in the Niagara Falls, N. Y., plant of American Magnesium Corp. and was transferred to the Cleveland plant in 1940.

Michiana Products Corp. announces that **A. J. Popovich**, formerly metallurgical engineer with Allis-Chalmers Mfg. Co., is now in charge of northern Indiana territory with offices at the plant in Michigan City.

John W. Lohnes, formerly manager of sales for the International Graphite and Electrode Corp., has been appointed vice-president in charge of carbon and graphite sales for Speer Carbon Co. and its subsidiary, International Graphite and Electrode Corp., of St. Mary's, Pa.

Eugene H. Kinelski has left Cornell Aeronautical Laboratory, Inc., to join the research and development department of Pullman-Standard Car Mfg. Co. in Hammond, Ind., as a corrosion engineer.

Henry H. Hoffman has been employed as metallurgical engineer in the research laboratory of Foster-Wheeler Corp., Carteret, N. J., since his graduation from Michigan College of Mining and Technology.

Tadeusz Sendzimir

To most metallurgists the name Sendzimir is associated with a cluster mill for the cold rolling of strip, wherein quite small work rolls are backed up by a cluster of larger ones, and in which extraordinary reductions to very thin gages can be made. **Tadeusz Sendzimir**, vice-president of Armzen Co. and inventor of that mill, is a Polish-born engineer who has devised other metallurgical improvements, among which is a hot-dip galvanizing process for which he recently received the annual award of the American Zinc Institute "for fundamental achievements in the art of galvanizing sheets". Such galvanized metal has been promoted for a dozen years by Armco Steel Corp. under trade name "Zincgrip". The process involves a rigorous surface treatment of the base material that eliminates the need of a flux, and certain modifications in the zinc bath which make for improved adherence and ductility of the coating as well as its uniform thickness.

Carl E. Schmitz, vice-president and director of engineering of the Crane Packing Co., Chicago, was elected vice-president at large of the American Society of Lubrication Engineers.

A. F. Greaves-Walker, **F. C. Schubart** and **Floyd Snow** have formed and are on the technical and operating staff of Titanium and Zirconium Metals Co., Inc., and are at present constructing a plant which will start commercial operation by September.

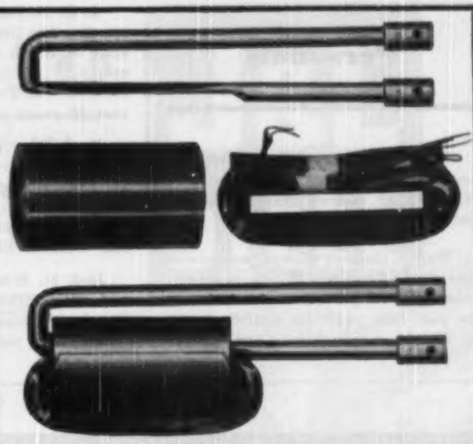
Karl L. Fetters

Among recent staff changes by Youngstown Sheet and Tube Co. are the appointments of **A. S. Glossbrenner** as vice-president in charge of operations, and two assistants, **Wm. H. Yeckley** (formerly general superintendent of the company's Campbell works) and **Karl L. Fetters** (formerly special metallurgical engineer). Dr. Fetters was born in Alliance, Ohio, received his university training at Carnegie Institute of Technology, and his doctorate at Massachusetts Institute of Technology, where he investigated the solubility of iron oxide in liquid iron under the direction of John Chipman. During the war he was connected with the investigation at Metals Research Laboratory of Carnegie Institute of Technology of the ingot practices necessary for high production of gun tubes made by the piercing of rounds. He joined Youngstown Sheet and Tube as openhearth metallurgist in 1936.

Firth Sterling Steel & Carbide Corp. announces that **C. E. Hughes** has been appointed district sales manager of the newly created southern district, with headquarters in Birmingham, Ala. Mr. Hughes has been with the company for 28 years.

Edward E. Reynolds, formerly research engineer at the Engineering Research Institute, University of Michigan, has been named metallurgist at the research laboratory of Allegheny Ludlum Steel Corp., Watervliet, N. Y.

HEAVY, LESS EFFICIENT and slower to assemble, was the original Weller Soldering Gun composed of the parts shown. Compare these with the fewer parts at right in the new Gun, and you'll readily see why the new streamlined Weller is so popular.



THE NEW WELLER SOLDERING GUN handles 250 watts; heats, ready for use, in five seconds; has longer range to get into the tight spots, and is equipped with spot light. Uses current only when trigger is operated. It is assembled faster. Requires no bolts or nuts. The ⅜" Revere Copper Rod that replaces the secondary coil in the transformer is sheared, flattened, and bent at right angles in a 200-ton press in a single operation.

COPPER TREATS YOUR PRODUCT BETTER WHEN YOU

Control Your Temper

Revere Copper Rod replaces Secondary Coil in Soldering Gun Transformer . . . reduces number of parts, makes for a speedier, more efficient assembly . . . also makes possible a lighter, more compact unit of increased capacity.

WHEN the Weller Manufacturing Company, Easton, Pa., was completing the development of its new electric soldering gun, they were confronted with this problem: The ⅜" Revere Copper Rod used to replace the secondary coil in the transformer had to maintain its rigidity yet be sufficiently soft so that during the shearing, coining, and bending operations there would be no breaking or splitting of the rod.

Revere's Technical Advisory Service recommended a certain temper copper rod. It was discovered that Weller was getting a twist in the rod when it was installed in the assembled gun. Other tempers were tried and tested. Then a copper rod of a slightly harder temper than the first was recommended. That was it! Proper temper was the key. Proper temper was also the key to the .291 dia. copper rod used for the Soldering tip itself. For this, too, had to retain its rigidity and yet remain soft enough to be coined, punched, and formed without fracture.

"In addition to being extremely helpful in arriving at the proper tempers, Revere also recommended that we specify our rod in multiple lengths, and thus save considerably on scrap. They were also helpful in solving the problem of attaching the brass sleeve to the secondary rod in our Soldering Gun," the Weller Manufacturing Company tells us.

So you see, Revere's interest in your problem does not stop with the recommendation of its products. Perhaps Revere can help you. Why not take your current problem to the nearest Revere Sales Office and see?

REVERE
COPPER AND BRASS INCORPORATED
Founded by Paul Revere in 1801
230 Park Avenue, New York 17, New York

Mills: Baltimore, Md.; Chicago, Ill.; Detroit, Mich.; Los Angeles and Riverside, Calif.; New Bedford, Mass.; Rome, N. Y.
Sales Offices in Principal Cities, Distributors Everywhere.

Personals

Wheelock, Lovejoy & Co., Inc., announce the appointment of **Edward S. Waltz** as district manager of its Detroit branch.

Wall Colmonoy Corp. announces that **R. L. Peaslee** has been appointed development engineer. For the past nine years he was employed by Wright Aeronautical Corp.

A. E. St. John has recently been appointed to the sales and engineering staff of Barth Smelting Corp., Newark, N. Y. Mr. St. John has been associated with Federated Metals for the past 25 years.

W. J. Riley, previously with International Harvester Co. and Dominion Engineering, has been named assistant quality control engineer at the Montreal, Canada, works of the Canadian General Electric Co.

Jack H. Mikula, who has been with the Milwaukee Gas Light Co. for about 20 years, has been named general sales manager of the company.

Walter F. Lynam, who has been with Latrobe Electric Steel Co. for the past 21 years, has been transferred from Pittsburgh, Pa., to St. Louis, Mo., where he will be southwest sales manager.

C. C. **Patton** has been transferred by the Western Electric Co. from the Hawthorne works to the new plant at Indianapolis where he will be toolsteel engineer and metallographer.

Donald E. Matthieu has resigned as assistant to the superintendent of the Birmingham, Ala., plant of the American Brake Shoe Co. to accept the position of metallurgist for the Alabama Pipe Co., Anniston, Ala.

Leonard C. Grimshaw has recently joined Firth Sterling Steel & Carbide Co. as assistant chief metallurgist. He was with the Latrobe Electric Steel Co. for 17 years and during the last three years has been looking after stainless clad patent interests of the late P.A.E. Armstrong.

Hugh P. Gibbons is now an engineer with the Standard Foundry Div. of F. J. McCarthy, Inc., Cadillac, Mich.

Ohio Crankshaft Co., Cleveland, has named the winners in its "Economy in Production" Contest. **John Nelson**, engineer at Commercial Shearing and Stamping, Youngstown, Ohio, was the recipient of the first prize of $1000. **L. F. Groves**, works metallurgist at Allis-Chalmers Mfg. Co., LaPorte, Ind., was awarded the second prize of $500 and **George S. Bidigare** and **R. E. Van Deventer**, metallurgists at Packard Motor Co., Detroit, received the third place and $250.

Universal-Cyclops Steel Corp. announces the promotion of **J. L. Stewart** from sales representative to assistant district manager of the Chicago branch and the appointment of **R. L. Springer** to the position of assistant district manager of toolsteel sales for the Chicago branch.

Following graduation from the Pennsylvania State College in June 1950, **William W. Lynch, Jr.**, has been employed as a metallurgist in the laboratory of the Universal-Cyclops Steel Corp., Titusville, Pa.

Fred H. Eckert has been employed as a technical trainee in the Massena, N. Y., blooming mill of Aluminum Co. of America.

Vladimir S. Zacharenko has recently been appointed materials testing engineer, Westinghouse Electric Corp., Sunnyvale, Calif.

JALCASE 10

J&L STEEL

- - - - - - the top grade of J&L
cold finished JALCASE - - - - WITH
HIGH MECHANICAL PROPERTIES

. . . and all the high machinability properties of other Jalcase grades

When the shop bull-sessions get started on "better than average" steels, and the boys get down to fine points, you can be sure that Jalcase 10 (AISI No. C-1144) will come up for discussion. That's because Jalcase 10 is the grade of cold-finished Jalcase steel made for those tough and "in between" applications.

Many times finished part specifications call for a high degree of hardness—but not as high a degree as that obtained through heat treating of the finished part. In these applications, manufacturers and machinists have found it profitable to use Jalcase 10 and dispense with heat-treating processes altogether.

Machinists who know their stuff also know that Jalcase 10—the highest carbon grade of Jalcase—has high mechanical properties. They know that Jalcase is the original cold-finished, open-hearth, free-machining steel. They know that Jalcase 10 has over 25 years of research and experience behind every ton produced.

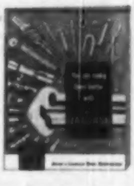
Interested in some technical data? Here are the chemical properties and mechanical properties of Jalcase 10:

CHEMICAL

Carbon Range	.40-.48
Manganese Range	1.35-1.65
Maximum Phosphorus	.045
Sulphur Range	.24

TYPICAL PHYSICAL PROPERTIES

Tensile Strength	134,050 lb./sq. in.
Yield Strength	107,840 lb./sq. in.
Elongation in 2 inches	13.5%
Reduction of Area	35.7%
Brinell Hardness	269



If you haven't tried Jalcase 10 yet (many shops have, and like it, too), why not send for our booklet entitled "You Can Make Them Better with Cold-Finished Jalcase." This 16-page illustrated booklet gives you technical information, charts and graphs about Jalcase 10 (and the other nine grades of Jalcase, too) that will help you make better parts.

Write Today!

Jones & Laughlin Steel Corporation
405 Jones & Laughlin Building
Pittsburgh 30, Pennsylvania

☐ Please send me a copy of "You Can Make Them Better with Cold Finished Jalcase."

☐ I am interested in making a trial run on J&L Jalcase 10. Please have a representative call.

Name__________

Title__________

Company__________

Address__________

JONES & LAUGHLIN STEEL CORPORATION

From its own raw materials, J&L manufactures a full line of carbon steel products, as well as certain products in OTISCOLOY *and* JALLOY *(hi-tensile steels).*

PRINCIPAL PRODUCTS: HOT ROLLED AND COLD FINISHED BARS AND SHAPES • STRUCTURAL SHAPES • HOT AND COLD ROLLED STRIP AND SHEETS • TUBULAR, WIRE AND TIN MILL PRODUCTS • "PRECISIONBILT" WIRE ROPE • COAL CHEMICALS

Personals

W. H. Mathesius ⊕ has been transferred by Laclede-Christy Co. from St. Louis to be general manager of the Chicago Retort and Fire Brick Div. in Ottawa, Ill.

Thomas J. Smith ⊕ is now employed as metallurgist by Wesson Metal Corp., Lexington, Ky., in production of cemented carbide tool tips.

Marion R. Calton ⊕, a May 1950 graduate from Missouri School of Mines and Metallurgy, is now engineer trainee for the Caterpillar Tractor Co., Peoria, Ill.

Charles L. Carlson ⊕ has recently joined Firth-Sterling Steel and Carbide Co., McKeesport, Pa.

R. Carson Dalzell, past-chairman of the Rome, N. Y., Chapter of the American Society for Metals, has been appointed to the staff of the U. S. Atomic Energy Commission's reactor development division. Dr. Dalzell was previously chief technical advisor, Revere Copper and Brass, Inc.

Fred A. Kaufman ⊕, formerly sales manager of the welding electrode division of the McKay Co., Pittsburgh, has been promoted to general sales manager of the company.

Ipsen Industries, Rockford, Ill., announces that **R. W. Krogh**, formerly assistant works metallurgist for Allis-Chalmers Mfg. Co., has joined its organization and will take over metallurgical duties and complete charge of the laboratory.

The Midvale Co., Philadelphia, announces the appointment of **M. Worth Acker** ⊕ as chief engineer. Mr. Acker, who was formerly chief metallurgical engineer, has been with the company since 1936. **Edward L. Murphy** ⊕ has been named engineer of tests. He was formerly assistant engineer of tests.

Bani R. Banerjee ⊕, formerly of the faculty of Illinois Institute of Technology, is now research engineer in the engineering research division of the Standard Oil Co., Chicago.

Robert W. Graham ⊕ has been promoted from assistant general superintendent of the Homestead works, Carnegie-Illinois Steel Corp., to general superintendent of the Duquesne, Pa., works.

Ivan L. Nichols ⊕, formerly with the U. S. Smelting, Refining and Mining Co., Midvale, Utah, is now a metallurgist for the Geneva Steel Co., Geneva, Utah.

Having graduated from the University of Pittsburgh in June 1950, **John Lewis Hill** ⊕ has accepted a position as metallurgist in training for the Allegheny Ludlum Steel Corp., Brackenridge, Pa.

Harold Meese ⊕, formerly senior metallurgist with Wheeling Steel Corp., Steubenville, Ohio, has accepted a position as assistant professor in the metallurgical engineering department of Michigan College of Mining and Technology, Houghton, Mich.

Perry L. Holsinger ⊕, who graduated from Ohio State University in June 1950, has been assigned to the metallurgical division of the Aluminum Co. of America at the New Kensington, Pa., works.

Bill Bauer ⊕ is now working at the P. R. Mallory Co., Indianapolis, as a metallurgical engineer, having received his B.S. degree from Antioch College in June 1950.

C. H. Fitzwilson ⊕, formerly service metallurgist with Carnegie-Illinois Steel Corp., has been transferred to the Columbia Steel Co., San Francisco, Calif., as metallurgical engineer of flat rolled products.

Advertisement

ELECTROMET *Data Sheet*

A Digest of the Production, Properties, and Uses of Steels and Other Metals

Published by Electro Metallurgical Division, Union Carbide and Carbon Corporation, 30 East 42nd Street, New York 17, N. Y. • In Canada: Electro Metallurgical Company of Canada, Limited, Welland, Ontario

CHROMIUM...key metal for strength, corrosion resistance, and heat resistance

Chromium is one of the most important alloying elements in iron and steel metallurgy since it markedly improves certain chemical and physical properties.

Increases Strength

The strength of steels is greatly increased by chromium because it retards the transformation of certain constituents during rapid cooling.

This makes it possible to obtain great depth of hardness in high-carbon steels, toughness in structural steel, and high strength and ductility in heavy sections. Chromium also increases resistance to shock by refining the grain of the steel.

Of all the alloying elements, chromium is probably the least expensive for increasing the tensile strength of steel. Additions of as little as 0.25 to 1.25 per cent chromium will increase the chill and hardness of the steel, as well as the tensile strength. In copper, aluminum, and other non-ferrous alloys, chromium provides increased strength, also.

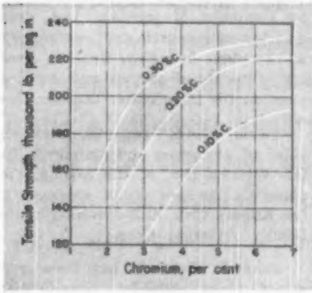


Fig. 1. Chromium increases the tensile strength of air-cooled steels of varying carbon content.

Imparts Corrosion Resistance

Commercially, chromium is added to steel and iron in amounts up to 30 per cent for the purpose of improving corrosion resistance.

In general, as the chromium content is increased with a given carbon content, the resistance of the steel to corrosive media becomes greater. The well-known "stainless" steels resist corrosion because substantial percentages (usually 12 per cent or more) of chromium are present.

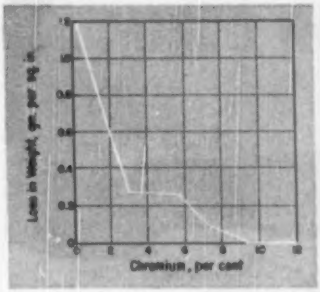


Fig. 2. Results of atmospheric corrosion tests on low-carbon steels of different chromium contents after 10 years of exposure to an industrial atmosphere.

Improves Heat Resistance

In both cast iron and steel, chromium provides good resistance to deterioration from heat. The use of chromium-alloyed iron and steel where high temperatures are encountered, for example, helps to prevent oxidation, which would ruin equipment. As little as 1 to 2 per cent chromium is added to cast iron to improve oxidation resistance and reduce growth of grate bars subject to high temperatures. Oxidation resistance improves progressively as the chromium is increased. Steels containing as little as 5 per cent chromium show good life at temperatures up to 1200 deg. F. For higher temperatures, appropriate steels of higher chromium content may be selected. Steels containing 25 to 28 per cent chromium give satisfactory service at temperatures up to 2100 deg. F.

Alloy cast irons with 15 to 30 per cent chromium are commonly used for applications requiring resistance to severe heat and abrasion.

In non-ferrous alloys, also, chromium is an important constituent for heat and corrosion resistance. It is used in the production of non-ferrous metal-cutting tools, chromium bronzes, and electrical resistance alloys.

Available Alloys

Chromium is produced by ELECTROMET in the forms listed below which are suitable for every use of the iron, steel, and non-ferrous metal industry.

Alloys of Chromium and Their Uses

Low-Carbon Ferrochrome	For production of corrosion- and heat-resistant steels, commonly known as the "stainless steels," as well as special high-temperature alloys in which a low carbon content is desirable.
High-Carbon Ferrochrome	For production of chromium-bearing steels that do not require low percentages of carbon. Also used for adding chromium to cast iron.
Nitrogen-Bearing Ferrochrome	For reducing grain size and improving physical properties of high-chromium steels.
Ferrochrome-Silicon	Used in the production of stainless steels for adding chromium to the bath, and for reducing oxidized metals in the slag back into the bath.
Ferrosilicon-Chrome	Readily soluble material for making either furnace or ladle additions of chromium to steels.
"SM" Ferrochrome	Readily soluble material for making chromium additions to steel or cast iron in either the furnace or the ladle.
Foundry Ferrochrome	Especially for use in making ladle additions of chromium to cast iron.
"CMSZ" Mix	Combination hardening and graphitizing mixture for use as a ladle addition in making high-strength cast iron having good machinability.
Chromium Metal	For use in non-ferrous chromium-bearing alloys, such as electrical resistance alloys, high-temperature and corrosion-resistant alloys, metal-cutting tools, chromium bronzes, and certain high-strength aluminum alloys.
Electrolytic Chromium Metal	Contains a minimum of 99 per cent chromium. For use in the production of non-ferrous alloys, where even small amounts of impurities would be objectionable.
"EM" Chromium Briquets	For adding chromium to cast iron in the cupola.

Personals

Orlo E. Brown, Jr.,, formerly chief metallurgist at Western Gear Co., has been appointed research metallurgist with Robertshaw-Fulton Controls Co. at its West Coast research laboratory in Hollywood, Calif.

Charles D. Townsend announces the establishment of Professional Expediting Service, Fort Wayne, Ind., for market surveys, plant layouts, location of hard-to-find items, preventive maintenance and the placing of new products into production.

Richard T. Haubrich is now employed as supervisor in charge of the plating, heat treating and spray painting departments of the Greist Mfg. Co., New Haven, Conn.

Harry E. Miller, who graduated from the University of Kentucky in June 1950, is now employed as a metallurgist with Armco Steel Corp.'s research department, Middletown, Ohio.

Edwin N. Hess has accepted a position as trainee in the inventory and metal control division of Reynolds Metals Co., at the Phoenix, Ariz., extrusion plant.

N. S. Spence has been promoted by Dominion Magnesium, Ltd., from director of research and development at the plant in Haley, Ont., to director of technical service and development at the main office, Toronto, Ont.

David Lewis, 2nd,, formerly chief of processes and standards for the Wichita Div. of the Boeing Airplane Co., is now senior engineer at the Kansas City, Kan., division of the Bendix Aviation Corp.

John R. Vogt has been promoted from assistant metallurgist, Bohn Aluminum & Brass Corp., Detroit plant, to metallurgist at the South Haven, Mich., plant.

Norman F. Tisdale, Jr.,, a recent graduate from Massachusetts Institute of Technology, is at present in Europe touring various metallurgical installations, but on his return he will join the Molybdenum Corp. of America.

Charles S. Haughey has been transferred from operating engineer in the erection department of Surface Combustion Corp., Toledo, Ohio, to engineer in the patent department.

Personals

Fred Foyle is now a junior metallurgical recorder with Jones & Laughlin Steel Corp., Cleveland.

Geo. E. Maley, Jr., is now representing the Electro-Alloys Div. and American Manganese Steel Div. of American Brake Shoe Co. in the Pittsburgh area.

After graduating from the University of Kentucky in June 1950, **William E. Wardman** is now employed by Armco Steel Corp., Ashland, Ky., plant.

Thomas L. Chase, formerly with Williams & Co., Inc., has joined the Western Automatic Machine Screw Co., Elyria, Ohio, as metallurgical engineer.

Louis S. Castleman, who received his Sc.D. from Massachusetts Institute of Technology in June 1950, is employed as metallurgist by the Atomic Power Div., Westinghouse Electric Corp., Pittsburgh.

Robert C. Lindsay has left his position with the Utica Drop Forge & Tool Corp., to enroll at Wharton Graduate School of Business and Finance of the University of Pennsylvania, Philadelphia.

C. J. Bier, formerly with Powmetco, Inc., has accepted a position as metallurgist with Radio Cores, Inc., Oak Lawn, Ill.

Harry P. Kling has been named senior engineer in the theoretical metallurgy section of the metallurgical laboratory, Sylvania Electric Products, Inc., Bayside, N. Y.

Lewis I. Field, Jr., who received his B.S. from Carnegie Institute of Technology in June 1950, has joined the training course of Bethlehem Steel Corp., Bethlehem, Pa.

Charles M. Blood has accepted an appointment in the chemical operations division of the Oak Ridge National Laboratory, Oak Ridge, Tenn.

General Electric Co. announces that **Howard L. Franks** has been named manager of sales personnel and control of the chemical department. Mr. Franks was previously director of sales for the Merrill Brothers in Maspeth, N. Y.

Arnold P. Litman has been appointed chief metallurgist of Union Wire Rope Corp., Kansas City, Mo.

Where light is too coarse...
The detail needed in electron micrography demands a fine-grain emulsion on glass—with enough sensitivity to permit exposure time less than 5 seconds. The best all-around material for this purpose is the Kodak Lantern Slide Plate, Medium. For occasional work requiring slightly higher contrast, there is the Kodak Lantern Slide Plate, Contrast. Both come in the standard electron microscope sizes, 2″ x 2″ and 2″ x 10″, available at your Kodak dealer. And for information on equipment for replica preparation and shadow-casting of specimens for electron micrography, write Eastman Kodak Company, Industrial Photographic Division, Rochester 4, N. Y.
ELECTRON MICROGRAPHY
...an important function of photography
Electron micrograph of zinc oxide smoke particle shadowed with chromium (X49,000). Courtesy Argonne National Laboratory.
Kodak

British Experience With All-Basic Openhearth Furnaces*

MORE EXTENSIVE application of basic refractories in openhearth furnaces is of interest in British steelmaking research as a possible means of obtaining increased tonnage from existing facilities. The desirable refractory qualities of basic brick are well recognized; however, the development of a satisfactory basic roof has been impeded by the excessive weight, high coefficient of expansion, loss of strength at operating temperatures and tendency toward growth exhibited by the material.

Just prior to the recent war, Stewarts and Lloyds, Ltd., installed a basic roof, presumably of chrome-magnesite brick from Austrian sources, and obtained a life of 1400 heats. Other trials at that time had indicated promise although the high cost of the imported brick was an economic deterrent. During the war several sea-water magnesite plants were constructed in Great Britain and with the resultant lowered cost of basic brick from these sources interest has been renewed in developing the all-basic openhearth.

The recent decision to abandon the traditional weekend shutdown of the British melting units is cited as one reason for expecting better success in current experiments with basic refractories.

The Detrick and the Radex methods for suspending basic roofs are discussed. The former, involving individual suspension of each brick, is well known to American furnace operators; a British modification of this design incorporates an automatic skewback loading arrangement to aid in controlling the roof. The Radex design developed in Austria embodies a spring-loaded skewback channel and a series of ribbed courses suspended from curved girders. Between the suspended courses are three to five courses of smaller brick supported only by the natural arch, and keyed or jointed to the rib bricks. This apparently has been done on furnaces that are small by American standards.

The first two postwar all-basic furnaces in England went into service in November 1948; since then four additional furnaces have been placed in operation and two more are under construction. No mention is made of the size of these furnaces but it is probable that they do not approach the capacity of openhearths constructed in the United States during recent years. An all-basic furnace operated by Steel Peech and Tozer, Ltd., on all-cold charge gave a roof life of 325 heats, compared with 125 for silica and was reported as melting 16 heats per week compared with 14 usual with a silica roof. Operating temperature occasionally was as high as 3100° F.

The objective of the British Iron and Steel Research Association in the various tests under way is the evaluation of brick performance, types of suspension, and refractory quality, in order to develop an all-basic furnace that will be economically successful. S. FEIGENBAUM

*Abstracted from *The Engineer* (London), Feb. 10, 1950.

German Advances in Heavy Nonferrous Metals*

A NUMBER of teams of investigators, both British and American, visited Germany shortly after the end of the war, inspected manufacturing plants, and interviewed engineers and management in those regions occupied by the Allies ex Russia. Each made an individual report of the findings. The British Intelligence has summarized the great number of documents in the respective fields of inquiry, and several of these summaries have now been printed. From a particularly comprehensive analysis of over 400 documents concerning activities in copper, lead, zinc and associated metals, the following is abstracted.†

Tin — No new developments in the metallurgy of smelting and refining of tin are reported. . . . . In the detinning of plated steel both the chlorine and alkali processes are used. Sodium stannate, made by the latter process, yields tin of 99.9% purity on smelting. . . . . Tin bronzes are melted and blown in a converter vessel, the oxides of tin, zinc, and lead being caught in a bag house. The mixture of oxides is remelted in a rotary furnace together with 15% anthracite, 6% soda ash, and 1% fluorspar. This burns off the zinc oxide (which again is caught in a bag house) and leaves an alloy of about 60% tin, 40% lead, which can be poured into ingots and used in foundry charges or further refined. A similar method is used for tin ore residues.

Lead — As for tin, no new developments were found in connection with the smelting and refining of lead ores. . . . . In the flotation process for the separation of galena (lead sulphide) from ores, it was found that particle fineness played an important part — strangely enough, a higher recovery was ob-

(Continued on p. 222)

*From "Nonferrous Metal Industry in Germany, 1939-1945", Report No. 23, British Intelligence Objectives Subcommittee, procurable from British Information Services, 30 Rockefeller Plaza, New York City 20.

†For summaries of information on lithium and titanium, see *Metal Progress* for February 1950, p. 252 and 257, respectively; a similar abstract on ferrous metals was published in the April issue, p. 508.

Zinc and Copper

(Starts on p. 220)

tained after coarser grinding. A mixture of sodium bisulphate and zinc sulphate is added to increase the amount of pyrites (iron sulphide) floating with the galena; sodium cyanide is then used to separate the two sulphides. Lead nitrate is added in the separation of pyrite and blende (zinc sulphide) concentrates. . . . . Copper dross containing lead is smelted in a small rotary furnace, 3 ft. in diameter, using pulverized coal for fuel and aluminous brick for lining — capacity, 6 tons in 6 hr.

Zinc — Sintering of low-grade materials containing considerable zinc is a troublesome operation. Details are given concerning the sintering conveyers, special bearings for gas fans, and ignition boxes for gas and oil firing. Cottrell electrostatic dust collectors were controlled by an automatic suction control device. . . . . Sulphite liquor is used in connection with the reduction of zinc oxide in vertical retorts and it was found that the nature of the wood from which the liquor was secured had an important bearing on the economy of the process, sulphite liquor from pine being better than that from beech to an extent of 30%. Details are given concerning retorts. . . . . Under the topic of electrolytic extraction there is a passing reference to documents on zinc-amalgam and zinc-amalgam-electrolytic extraction, two novel methods which were investigated by the Germans.

Copper — No new methods for smelting or refining were unearthed. (In German practice the smelting and refining of copper, zinc, lead and tin is integrated and interdependent.) The Germans paid a lot of attention to problems concerning treatment of copper scrap.

Furnaces, fuels and refractories saw no major improvements during the war. . . . . References are available concerning the manufacture of synthetic sillimanite (an aluminum silicate used for a refractory). Silica bricks containing 8% alumina are used for furnaces melting copper-base alloys. . . . . German practice uses Ajax-Wyatt furnaces for semi-continuous brass casting. For melting lead, mild steel pots last five times as long as cast iron. In brass

(Continued on p. 224)

Melting and Casting

(Starts on p. 220)

and bronze foundries, coke-fired furnaces melt copper-base alloys using 25 lb. of coke per 100 lb. of charge.

Melting — Only a few data are available on advanced melting practices. In melting copper-base alloys a flux consisting of 20% black oxide of copper, 25% sodium nitrate, 25% sodium chloride, 13% silica, 7% barium chloride, 10% sodium carbonate is used. Various fluxes for removing iron and aluminum from brass are given. Copper is usually added to lead-base alloys by pouring in a correct amount of molten phosphor-copper alloy at 930° F. The technique of alloying "Bahnmetall" for bearings (lead, hardened with calcium with or without sodium and a little aluminum) is reported as: "Melt lead with calcium-lead temper alloy and at 930° F. sodium and lithium are plunged into the molten alloy." The calcium-lead temper alloy (4% calcium) is made by first adding molten lead at 1475° F. to a molten mixture of calcium chloride and fluorspar. The mixture is constantly and thoroughly stirred and small amounts of aluminum added, followed by additions of calcium carbide. Stirring is continued for 4 hr.

Phosphor copper is made by packing copper turnings in a crucible around a former consisting of a 2-in. round steel rod whose bottom is 3 or 4 in. from the bottom of the crucible. When the turnings are packed the rod is withdrawn and a lid carrying a 2-in. steel tube fitted with a valve is luted on the crucible with a clay mixture. When the charge is red hot but not melted, pieces of yellow phosphorus are introduced into the crucible through the valve.

Rolling Mill Ingots — The surface quality was improved by mounting the mold on springs subjected to low-frequency vibrations.

Sand Casting — Only a small quantity of sand castings in copper-base alloys was made in Germany owing to the scarcity of copper. A "parting" powder used consisted of calcium carbonate with 1% of carnauba wax. A core binder having no linseed oil consisted of 78% limestone, 20% tar-pitch, 2% dextrine. The tar-pitch was sometimes replaced with half as much colophony resin. *(Cont. on p. 228)*

UNTIL WE KNOW!

If you want a "yes" or "no" answer right off the bat, please don't ask us whether we can accept your order for metal powder parts . . . for our answer may have to be "No." That's because we delay saying "Yes" until we have satisfied ourselves on two points: (1) Is the part adapted to production by the powder metallurgy process? (2) Will the powder metallurgy process work to the advantage of the customer, in lowered costs or improved performance?

Actually, thousands of parts now made by older methods could be made better or more economically by Moraine. Three simple rules determine whether any particular part meets our standards:

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Single Stage Kinney Pumps available in eight sizes: capacities from 13 to 702 cu. ft. per min. — for pressures to 10 microns Hg. abs. Compound Pumps in three sizes: 5, 15, and 46 cu. ft. per min. — for pressures to 0.5 micron Hg. abs. or lower.

Vacuum metallizing and coating, originally developed for bomb sight lenses and aviators' goggles, is now applied to many everyday products — such as automobile ornaments, refrigerator name plates, costume jewelry, children's toys, and scores of other items. In many cases, the atom-thick coating it produces is really a beauty treatment. In others, vacuum metallizing permits important functional improvements. Metallized bomb sights, for example, permit direct sight into the sun. Again and again, the vacuum metallizing beauty bath has improved products and increased their sales potentials.

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Making old things better
Making new things possible

KINNEY Vacuum Pumps

Casting of Brass

(Starts on p. 220)

Casting of Brass in Permanent Molds — A 35% zinc-copper alloy with 1% aluminum was cast in permanent molds made of standard grades of cast iron. A semicentrifugal process consisted of the use of a rotatable mold mounted on a vibrating table. Castings weighed 6 to 10 lb., and were used for valves and pipe fittings. A single die or mold would make 200 to 400 castings in 8 hr.; the life would be from 20,000 to 40,000 castings. . . . . No evidence was found that copper-base alloys were cast by the pressure die casting methods used for aluminum or zinc alloys.

Centrifugal Casting — In general, the German methods are those in regular use elsewhere. For casting brass or bronze tubes or cylinders, a mold liner in the form of copper sheet 0.3 mm. thick is said to give an improved surface. . . . . Special data are available for the casting of bearing bushes both centrifugally and statically. The metal used is mostly copper containing 30% lead, although a somewhat unusual alloy (0.2% graphite, 10% tin, 15% antimony, 1.75% copper, remainder lead) known as "Gittermetall" is used for many bearings. In its manufacture the powdered graphite is mixed in the molten alloy at a temperature of 480° F. . . . . The coating of gear blanks is done in one foundry by heating them in a vapor of stannous chloride. The gear blank is first plated with copper to a depth of 0.1 to 1.0 mm. and is then exposed at 1300° F. to a hydrogen atmosphere containing 5% by volume of hydrochloric acid that has previously been circulated over a bath of tin. Stannous chloride is reduced, producing a copper-tin alloy on the surface of the blank. Hydrogen and HCl are recovered.

Welding and Soldering — "Canzler" copper welding rods are used, of composition 1% silver, 0.05% phosphorus, remainder copper. In their manufacture the copper is melted, silver is added, followed by deoxidation with phosphorus. Cast rods are coated with flux consisting of 5 parts boric acid, 2 parts sodium fluoride, 2 parts sodium chloride, and 1 part lithium chloride, mixed with water to produce a paste. . . . . An aluminum solder of

(Continued on p. 230)

Nonferrous Alloys

(Starts on p. 220)

95% zinc, 5% aluminum, 0.01% titanium is used for soldering aluminum ware. . . . . The flux in cored solders contains 94% resin, and 6% orthotoluidine hydrochloride. Glycerol and ammonium chloride flux is used with solder powder of varying tin content.

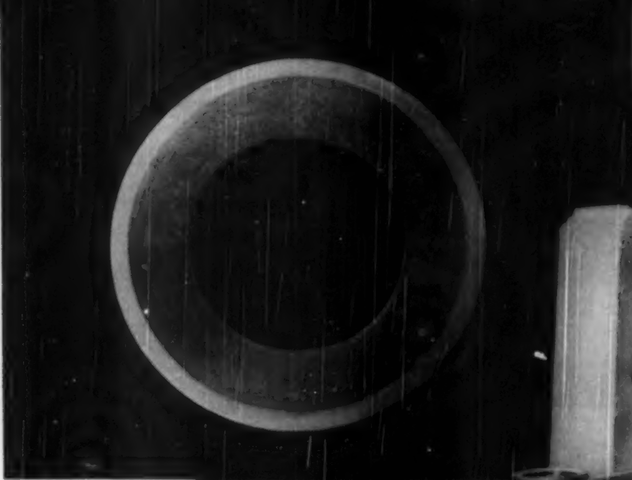
Metal Powders — No new methods of manufacture were discovered. . . . . Tin, lead and zinc powders are produced by air or steam atomizing; aluminum and iron, mainly by steam. Copper powders are made mainly by the electrolytic process, acid copper sulphate being used without colloids.

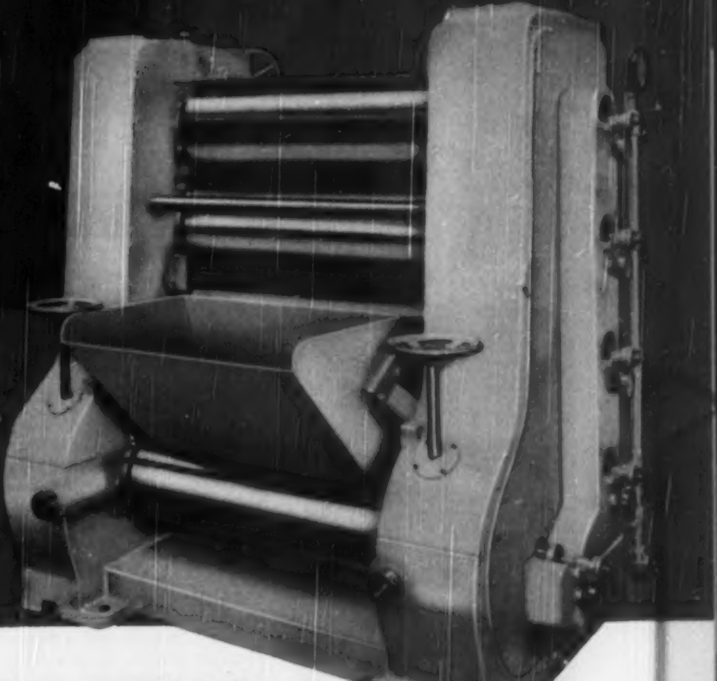
Research in Alloys — Wartime research was principally confined to the Kaiser Wilhelm Institute and the Technical High School at Stuttgart. A new zinc-base alloy (30 to 32% aluminum, 1 to 3% copper, remainder zinc) was extensively studied and is reported to be workable either hot or cold, to have good casting properties and bearing characteristics. As cast, its tensile strength is 57,000 psi., its elongation 6 to 10%; as extruded, its tensile is 67,000 psi., elongation 10 to 12%. . . . . Heat resisting alloys having 10 to 40% tantalum, 50 to 80% nickel and 10 to 25% chromium were developed and the effects of various elements on their heat resisting properties were studied. . . . . Less than 0.006% of oxygen is required to render lead highly corrosion resistant.

Applications — Several interesting uses (substitutions of well-known alloys) include back axles for tractors made of zinc-base alloy (!), bearing metals of Bahnmetall, and lead-copper containing 35% copper. Lead-base bearings for automobile connecting rods were made of 10% tin, 14% antimony, 1.4% copper, remainder lead. Some high-duty springs were made of 70-30 brass containing about 1% each of silicon, aluminum and iron. Heat resisting parts for jet engines contained 20% copper, 2 to 3% aluminum and remainder iron.

Food Cans — A can-welding machine was developed giving a "high speed of 110 to 120 cans per min.". (In the United States, the soldered side seam method is used, giving 300 cans per minute.) Contrary to

(Continued on p. 232)





DUAL METAL ROLLS

Centrifugally cast dual metal roll shells have found wide acceptance with equipment builders who use chilled iron rolls for grinding or processing such commodities as ink, paint, pigments, chocolate, paper, flour, cereals and soap.

One of these equipment builders is the J. M. Lehmann Company, Inc. of Lyndhurst, New Jersey, who has standardized on our centrifugally cast dual metal chilled iron-gray iron rolls for their soap, ink and chocolate mills which they identify as "CDM" Rolls (centrifugally cast dual metal), a Lehmann trademark.

Utilizing centrifugal force and temperature, our dual metal casting process makes possible the production of grinding and processing rolls requiring a hard outer shell of white iron for the wearing surface and a soft, readily machinable gray iron core to facilitate the insertion of driving shafts. These two dissimilar metals are cast separately but are metallurgically bonded so as to provide an *accurately controlled and uniform chill depth and also uniform hardness* in both the hard outer shell and the soft gray iron core.

A number of two-metal cylindrically shaped combinations are now being made for equipment manufacturers who require metallic structures which have two working surfaces and where performance requirements imposed on these surfaces are quite dissimilar.

U. S. PIPE AND FOUNDRY CO.

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AMERICA'S LARGEST PRODUCER OF CENTRIFUGALLY CAST FERROUS METAL PRODUCTS IN TUBULAR FORM

Nonferrous Alloys

(Starts on p. 220)

American experience, the manufacture of cans from electrolytic tinplate was not a success in Germany. "Black-plate" cans with phenolic resin coats, welded from bonderized or nonbonderized strip, were used in Germany for all nonacid vegetables, meat and fish. Can bodies of multiple length were extruded.

ABSTRACTOR'S NOTE: It is evident that antimony was used in bronze to save tin to a greater extent than in the United States. The use of orthotoluidine hydrochloride in resin flux is worthy of consideration, also the process for the manufacture of "Bahnmetall" (hard lead bearing metal). H. J. ROAST

Measurement of Strain*

THE measurement of stress and strain is of great importance to physicists, metallurgists and all varieties of engineers. This 114-page book could never satisfy the specialist. The review presented here will attempt to answer two questions: Can a metallurgist understand the book? Can he derive value from it? As the book consists of twelve articles by different authors, the questions will be referred to each article in turn.

The first article is by the late Eric Jones and deals with "Some Physical Characteristics of the Wire-Resistance Strain Gage". The subject is of enormous practical importance and is relatively new. The author describes schematically the gages used and the materials applied in their manufacture, but the troubling question of how a gage glued to the test sample could follow the strains in the latter without an indeterminate and irregular lag, is answered only categorically. It is stated that such a question existed but was found groundless. A bit of simple mathematics regarding the stresses in the paper base,

(Continued on p. 234)

*Review of "The Measurement of Stress and Strain in Solids", Institute of Physics, London, 1948.

Strain Measure

(Starts on p. 232)

the cement and the filament might have helped a great deal.

The analysis of the working conditions of the gages (sticking on, drying, waterproofing, and so on) is quite good.

The part of the article dealing with the electrotechnical characteristics of the measurement and recording of the signals produced by the gage will probably leave no definite picture in the mind of the metallurgical reader, except that a low-resistance gage is better when a micro-ammeter is used and a high-resistance gage when the recording is done by a cathode-ray tube. The metallurgist would like to know which method is more reliable and more easily applied, but he gets no answer here. Will the builder of the instruments need the information contained? He needs much more — but has to produce it himself.

Of great importance is the possibility of using a resistance gage in fatigue testing. That possibility is mentioned by the author and he shows that for duralumin the gage will work up to the impossible (at present) frequency of 40,000 vibrations per second. But how could this sensitivity and freedom from hysteresis of the resistance gage be used on springs or revolving shafts? Of that the author says nothing.

Next comes the article by F. Aughtie, "The Use of Resistance Strain Gages in Combination, With Particular Reference to the Measurement of Component Loads". This is another important subject. A description of one actual example of the use of a number of strain gages in combination might give the metallurgist and the test engineer a clear picture of that possibility. But Aughtie prefers to show rather tedious mathematics, completed by J. G. Cooper in Appendix 2. True, he examines one hypothetical case — not precisely defined — in numerals instead of symbols, but it does not help the metallurgist or engineer much. The nonspecialist would have to spend fully two days to follow the mathematical development.

The third article, "High-Frequency Strain Gages", by E. P. George, is only a suggestion, stated quite clearly but incompletely. High-frequency gages, based on ferromagnetic ma-

(Continued on p. 236)

Strain Measure

(Starts on p. 232)

terials, must have a high temperature factor; therefore, they could be used only under controlled temperature conditions.

The fourth article, a mere note on the use of resistance strain gages in ships, by F. B. Bull, is less than one page long. It states that Baldwin-Southwark strain gages were used with satisfaction in static trials.

The fifth article, by W. A. P. Fisher, "A Review of Some Recent Developments in Photoelasticity", concerns that method of determining stress distribution in a metal part, on the basis of an analogy with the distribution in a transparent model. The article contains a number of beautiful photographs (all researches in photoelasticity do); for instance, the beautiful front-page color photograph of a hammer and a nail that is being struck in an eccentric manner. Incidentally, no hammer has a handle of the same material as the head, so why was not the handle of the model made separately and the head provided with a hole for its insertion?

The section on separation of principal stresses is explanatory, but its Part I on the four-point influence method is too brief and too awkwardly written to be understood by anyone who has not studied the method as a specialist. Neither is the interferometer method described in a manner permitting the engineer to understand how it works and what results are obtained. He does learn that "the interferometer cannot be had for a few shillings".

Very simple and practical is the article by H. McG. Ross, "Photography of Photoelastic Stress Patterns". It gives the reader a clear general idea and pretends to give no more than that.

J. W. Fitchie's "Note on Time-Edge Stresses in Photoelastic Models" concerns a detail pertinent to the choice of a suitable plastic for the models.

C. E. Phillips, in his "Review of Some Strain-Measuring Devices", gives a very clear, but much too brief, picture of devices intended for direct reading of strains. It is unfortunate that he does not tarry longer on the description of instruments developed by the National

(Continued on p. 238)

Strain Measure

(Starts on p. 232)

Physical Laboratories (of Great Britain). The precise determinations of the moduli of elasticity, and particularly of transverse contraction ratios, call for instruments of great range and a sensitivity of at least 0.000,010 or even 0.000,001 in., which should possess neither set nor lag of their own. A description of such instruments and of the methods of calibrating and using them is badly needed. Of course, it is not feasible to do it in an article of six pages. Glazebrook's "Dictionary of Applied Physics", while not up-to-date, is available everywhere and gives much more information, but even it is too brief. The subject would easily allow for 200 pages of terse, lucid text.

The ninth article, by D. E. Thomas, "The Measurement of Strain in Metals by X-Rays" is similar to the same author's recent contribution to the Institute of Metals [see review in *Metal Progress*, February 1949]. It is difficult to say for whom the article was intended. This reviewer must express his doubts as to the possibility of getting a precision of 1/50,000 from any but stress-free metals.

Article X is merely a note by K. J. Pascoe on "The Use of X-Rays for Investigation of Residual Stresses in Ship Structures". It states only that a mobile installation is being built by Hilger and that the sensitivity will be sufficient to tell whether a given spot carries stresses close to the yield point.

F. B. Bull, in a "Note on Acoustic Strain Gages", states that these gages are satisfactory on board ships and mentions a few things of a general nature, but gives no technical details.

The final article is by G. E. Bennett, a "Summary of Additional Electrical Methods of Strain Measurement". It is the longest in the series and attempts to handle in 20 pages a huge field of principles, basic instruments called "pickups", and auxiliary instruments. In places, it reads almost like a list of gadgets issued by a manufacturer, except that the latter would show how his instruments are used and what results can be obtained; such information is absent from the article. It tells the reader that there are pickups based on the variations of

(Continued on p. 240)

Strain Measure

(Starts on p. 232)

inductance and of capacitance and that the phenomena of magnetic permeability and magnetostriction can be used for measuring strain. We learn also that among the inductance gages there are moving-core type, variable-air-gap type and eddy-current type, but the precise meanings of the terms are not given. We learn that some of these gages weigh 1.5 g. and others about an ounce, but further on we find that their weight is a disadvantage in comparison with the resistance gages. We see a photograph of the variable-air-gap gage (Fig. 51) that weighs 1.5 g., but only a person that has already used them can tell how this gage is connected to the test sample.

The part of the article given to the description of auxiliaries is far more lucid and might be read profitably by the young practical physicist connected with the gage-making industry, who wants a picture of most of the existing methods of registering and recording the signals. But it will scarcely be of value to the testing engineer, who will choose his instruments from performance data, not from a general description of the principle used.

M. G. Corson

Stress Corrosion*

THE susceptibility to stress corrosion of a series of aluminum-base alloys subjected to various types of atmospheric exposures (industrial, sea shore, city and country) was investigated. Clad and bare aluminum – copper – magnesium, aluminum – 9% magnesium (half hard temper), aluminum – 4% zinc – 2.5% magnesium (nominal) and similar alloys containing small amounts of vanadium and chromium were used. [Actual compositions not given; the analytical values were "lost through military action".] The aluminum – zinc – magnesium alloy was tested as

(Continued on p. 242)

*Abstract from "The Effect of Atmospheric Exposure on the Stress Corrosion of Aluminum Alloys", by Gerhard Schikorr and Gunter Wassermann, *Zeitschrift für Metallkunde*, Vol. 40, 1949, p. 201-205.

THERE'S "IMPULSE BUYING" AT THE METAL SHOW

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* *From Attendance Report No. 4 in a continuing analysis of Metal Show visitors. Write for a copy.*

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Stress Corrosion

(Starts on p. 240)

water quenched and after a special heat treatment [not described] intended to diminish susceptibility to stress corrosion. One end of each strip cut from 1-mm. (0.039-in.) thick sheet was bent into a closed loop and fastened to produce a stress. To minimize variations in the procedure, all specimens (about 6000) were bent by the same person. Thirty-six loops of each alloy and temper were placed on wooden exposure racks at each of 17 places.

The effects of rainfall were determined by exposure in the open but under a roof of additional looped specimens at a few of the locations. To determine the general corrosiveness of the various atmospheres, specimens of electrolytically refined zinc and of Armco iron were exposed on the same racks for a month and the amount of corrosive attack determined by weight loss after the corrosion products were removed. In addition the sulphur content of the iron rust was determined. For comparison, laboratory tests were made in which the loops were one-third immersed in 3% sodium chloride solution at 160° F. The results were given as half life time, the time necessary for one half the specimens to develop a crack or a fracture, instead of the usual average time for the specimens to fail.

The water quenched aluminum – zinc – magnesium alloy was the most susceptible to stress corrosion. In the more corrosive atmospheres (industrial and sea shore) the half value time was 10 to 38 days, less than one third of that found under the more favorable conditions. Specimens of this alloy given the special heat treatment had a minimum half value time of 190 days, and increased to between 250 and 300 days in the less corrosive atmospheres. The half value time of the heat treated specimens varied appreciably less with differences in the type of atmosphere than did that of the water quenched specimens.

Of the other alloy compositions, only a very few specimens failed during a year's exposure. Consequently it appeared that these alloys were practically free from stress corrosion under the test conditions employed.

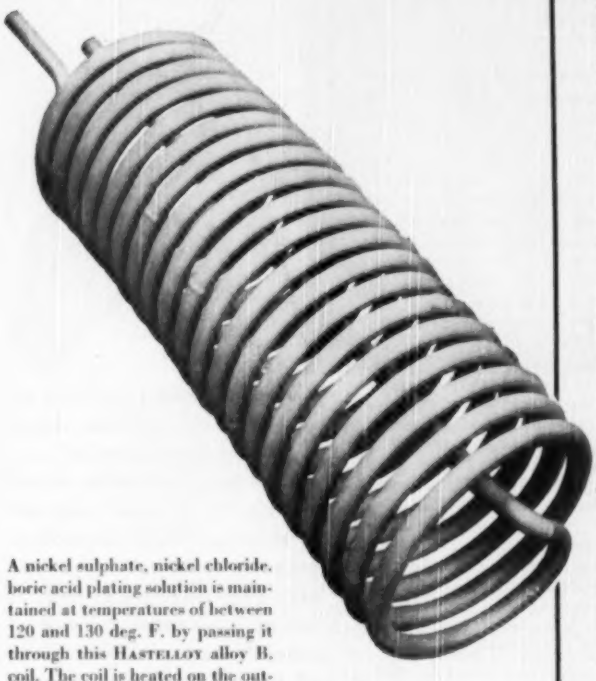
The magnitudes of the weight losses of the zinc test pieces were

(Continued on p. 244)

ONE YEAR'S SERVICE

resisting a nickel plating solution and live steam

...AND STILL NO SIGN OF WEAR!



A nickel sulphate, nickel chloride, boric acid plating solution is maintained at temperatures of between 120 and 130 deg. F. by passing it through this HASTELLOY alloy B. coil. The coil is heated on the outside by live steam under a 30 lb. pressure.

Used as a heat exchanger in a system designed to heat and cool nickel plating solutions, this HASTELLOY alloy B coil shows no sign of wear after one year's service. In operation the plating solution is on the inside of the coil and either live steam or cooling water are used on the outside to control the temperature of the solution at approximately 130 deg. F. The lead coils previously used had to be replaced every 3 months.

Alloy B was unusually successful here because it has high tensile strength and excellent thermal shock characteristics in addition to superior corrosion resistance. This combination of properties permitted the fabrication of the coil with walls that are thin enough to insure good heat transfer and, at the same time, strong enough to stand up under the impact of water hammer and the shock of sudden temperature changes.

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Stress Corrosion

(Starts on p. 240)

not in the same sequence with respect to geographical location as the half value times for the aluminum alloys, but in the ten most severe locations for the aluminum – zinc – magnesium alloy the weight loss for the zinc exceeded 0.1 g. per sq.m. per day. The value was less than this under the less severe conditions.

The sulphur content of the rusted iron exposed to industrial atmospheres increased about 0.033 g. per sq.m. per day. A lesser gain was found in the city and country atmospheres.

The water quenched aluminum – zinc – magnesium alloy specimens protected from rain by a roof showed lower half value times than specimens exposed at the same locations in the open. The heat treated specimens showed longer half value times when protected from the rain.

In the laboratory sodium chloride immersion test, the water quenched specimens of the aluminum – zinc – magnesium alloy failed in 30 to 65 min., while the heat treated specimens broke in 25 to 116 hr. The other alloys did not break in 50 days. In general these short-time tests indicated the susceptibility of the alloys to stress corrosion but gave no information as to the life of the loops in atmospheric exposure.

The relative merits of the half value time and of the average life as the best way of reporting results were discussed. Use of the half value time appreciably shortened the time necessary for completion of a test program, since the result was available when only one half the specimens had broken.

Electrodeposition of Tungsten Alloys*

BECAUSE of the low hydrogen overvoltage and the estimated value of −1.1 volts for the reduction of the WO_4^{--} to metallic tungsten, no success is anticipated in attempts to electrodeposit *(Cont. on p. 246)*

*Abstract of an article by F. W. Salt, *Murex Review*, Vol. 1, No. 5, 1949, p. 77-87.

Electrodeposition of Tungsten Alloys

(From p. 244) pure tungsten from aqueous solution of its salts. The article under review is devoted, therefore, to a survey of attempts that have been made to produce tungsten alloys with one or more of the metals iron, cobalt and nickel.

The present tendency is to deposit tungsten alloys from solutions of pH 7 or greater, and to use ammoniacal solutions of hydroxy-acids, such as citric, tartaric, malic, gluconic or hydroacetic, to increase the solubility of the codepositing metal in the bath. The throwing power of such baths appears to be as good as, if not better than, ordinary chromium baths, and as a result tungsten alloys might be expected to provide an advantageous substitute for chromium, particularly where hardness at elevated temperature is required. The inferior mechanical properties of the alloys, as presently developed, militate against widespread applications, however, and continuous operation of the baths is complicated because the rate of anode dissolution cannot readily be controlled by adjustment of bath composition or of current density. Also, an additional insoluble anode must be used to prevent accumulation of metal in the bath if cathode efficiency is low, as happens, for example, in the deposition of cobalt-tungsten alloys high in tungsten. The excessive loss of ammonia when working the baths at elevated temperatures is another disadvantage.

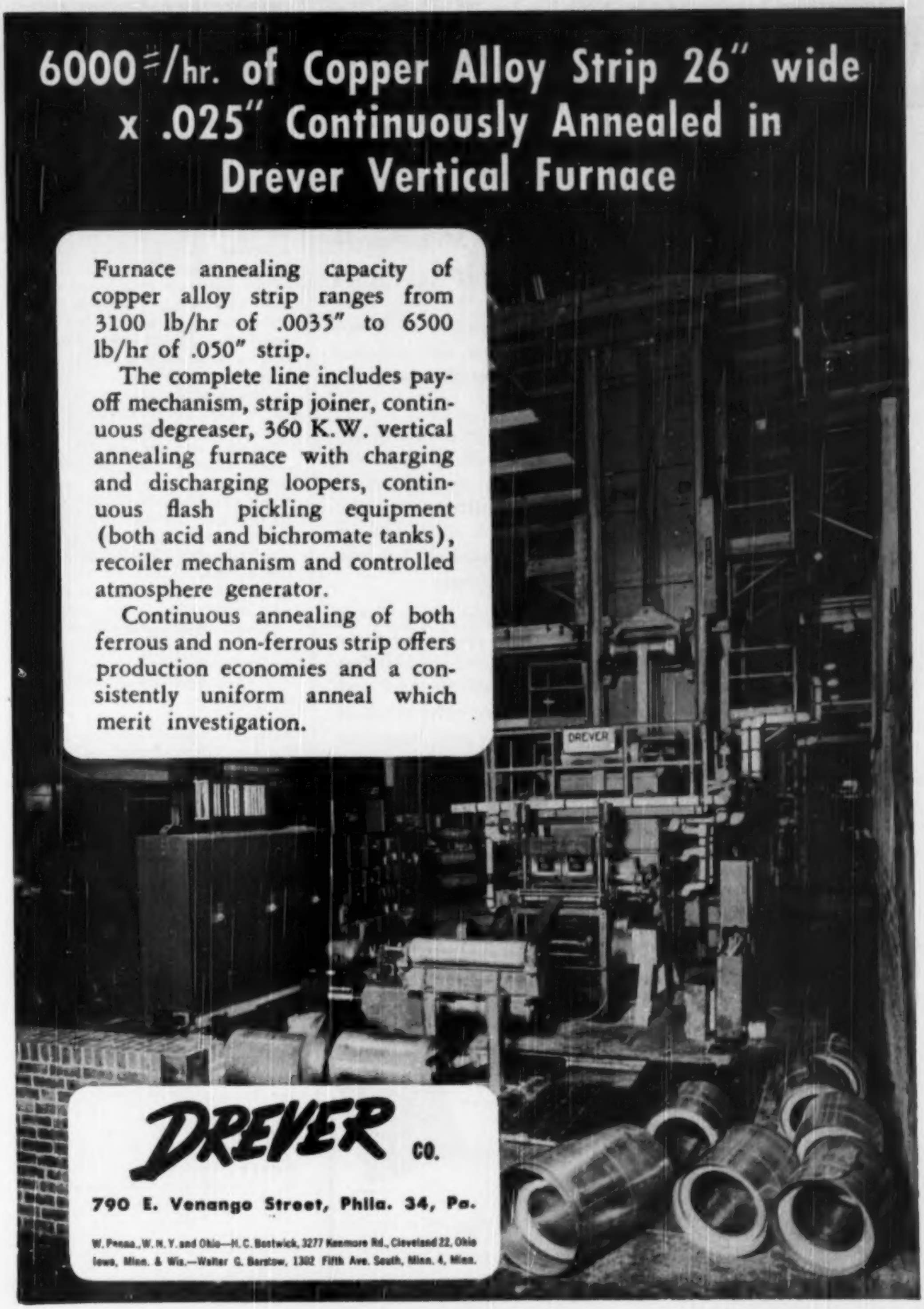
Under most favorable conditions alloy deposits varying in appearance from gray to bright, similar to chromium, can be obtained. The outstanding physical property of the alloys prepared by Brenner and co-workers at the National Bureau of Standards is their hardness, particularly after suitable heat treatment. Cobalt alloys containing 30 to 50% tungsten had a hardness of 500 to 600 Vickers, as deposited, and 800 to 900 Vickers after 1 hr. at 1100° F. With nickel alloys containing 20 to 30% tungsten, an initial hardness of about 600 Vickers was raised to 750, and with iron alloys having a 50% tungsten content, the hardness was increased from 800-900 to 1200-1400 Vickers in a similar treatment. Measurement of the hardness at 1300° F. of cobalt alloys containing 23% tungsten showed them to be comparable to Stellite (200 to 300 Vickers) at this temperature. The alloys are solid solutions and, as determined by a bending test, are brittle under all conditions of plating. The nickel and cobalt alloys had no apparent ductility when the tungsten exceeded 5%, but became ductile after heating above 1100 and 1650° F. respectively. The iron-tungsten alloys remained brittle in spite of a similar treatment. When their tungsten contents exceeded about 20, 30 and 50% respectively, the nickel, cobalt and iron alloys became nonferromagnetic. The chemical resistance of the alloys was, except against nitric acid, similar to that of the alloying metal. The rate of attack by nitric acid was reduced by the presence of tungsten. Cobalt-tungsten alloys were highly protective against 20% salt spray.

While it seems likely that much more research and development must be undertaken before practical plating baths are realized, results to date show promise of ultimate success. Lietzke and Holt of the University of Wisconsin, for example, proposed a bath in 1948 for the electrodeposition of iron-tungsten alloys of the following composition: 28 g. per l. of tungsten as $Na_2WO_4 \cdot 2H_2O$; 2 g. per l. of iron, as 50% each Fe^{II} and Fe^{III} (from $Fe^{II}(NH_4)_2(SO_4)_2 \cdot 6H_2O$ and $Fe^{III}NH_4(SO_4)_2 \cdot 12H_2O$ respectively); 66 g. per l. citric acid; and NH_4OH to pH 8. The bath is operated at 158° F. at a cathode current density of 5 amp. per sq.dm., using iron anodes. The cathode deposit contains about 53% tungsten. The plates are bright and shiny in appearance and show only a slight tendency to tarnish. They are extremely resistant to acid attack and must be treated with $HF + HNO_3$ for analysis.

Creep Tests*

CREEP of metals is a phenomenon of comparatively recent interest, starting about 1920 with the necessities of high-temperature equipment for power *(Cont. on p. 248)*

*Abstracted from National Bureau of Standards' Technical Report 1423 concerning "Influence of Strain Rate and Temperature on the Creep of Cold Drawn Ingot Iron", by Wm. D. Jenkins and Thomas G. Digges, *Journal of Research*, Vol. 43, 1949, p. 117.


6000#/hr. of Copper Alloy Strip 26" wide x .025" Continuously Annealed in Drever Vertical Furnace
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Creep Tests

(Starts on p. 246) and for chemical processing. As is well known, a tensile specimen carefully maintained at steady load and elevated temperature is measured for length at convenient intervals, and elongation versus time is plotted. If fracture results the curve shows three stages: the first stage, wherein an initial rapid stretch gradually slackens off; the second stage, wherein the curve is a straight line sloping upward — that is, the strain rate is constant; the third stage, wherein the curve turns upward.

Such a test represents conditions only for a specific temperature, load, and metal. How about other temperatures and loads? Systematic experimentation has indicated that if all testing conditions are constant except stress, and the rate of creep in the second stage is determined for a variety of stresses, the data plot as a straight line on log-log paper. This enables the testing engineer to predict the creep rate at stresses intermediate between actual experimental values, and to extrapolate somewhat.

Recent studies at the National Bureau of Standards have indicated that the above simplifications do not apply exactly to such single-phase metals as monel metal, copper and ingot iron. For example, the second stage of creep for ingot iron progresses not uniformly but in a cyclic manner. During a cycle, the change in extension for unit time ranges from relatively high to low (and sometimes even negative) values. The frequency and amplitude of these cycles taper off toward the end of the second stage of creep; they are most pronounced, also, at the lower temperatures and lower stresses. These cycles, it is believed, result from a combination of strain hardening, strain aging, and recovery of the iron.

Likewise, the average rate of creep of ingot iron as it varies with stress at a given temperature does not plot as a straight line, but bends downward with the slower and upward with the higher ranges in strain rate. A general pattern is followed, but the curves for various temperatures are not parallel. Thus, for this metal (ingot iron, initially cold worked 13% on area) it is not permissible to extrapolate the data to very slow strain rates (representing long service life) at 700° F.

Leaching Zinc Ores*

ECONOMIC recovery of zinc from low-grade oxidized ores and off-grade complex sulphide concentrates is of definite interest to the zinc industry, not to mention the user of zinc who is always hoping for an increased production and a lowering of cost. The authors' thoughts were directed to the use of the dithionate process because of their experience in using it for the extraction of manganese from low-grade ores. (Dithionates are salts of an evanescent acid $H_2S_2O_6$.)

In essence the process consists of leaching out the zinc with SO_2 gas in a calcium dithionate solution. The zinc sulphate is immediately converted into soluble zinc dithionate, which is freed from the insoluble calcium sulphate, together with other insolubles or ore residues by filtration. Milk of lime is then added to the filtrate, precipitating zinc hydroxide which is filtered from the calcium dithionate solution, dried and finally calcined to give zinc oxide with nearly 70% zinc.

Simple equations are given which confirm the underlying principles involved, and the statement is made that theoretically the process is completely cyclic with respect to the dithionate ion, the calcium dithionate required for reaction with the zinc sulphate being replaced by that formed by the reaction between zinc dithionate and calcium hydrate. In practice, of course, some dithionate would be lost in the various filter cakes, depending on the economic washing limits. In the leaching step, however, some of the SO_2 is oxidized to dithionate instead of to sulphate, so the dithionate losses are made up — at least in part.

Advantages of the process are:

1. Utilization of waste SO_2 gas.
2. Possibility of forming enough dithionate during leaching to make up for losses.
3. Separation of zinc from lead, gold and silver.
4. Recovery of zinc from solution by precipitation with lime.
5. Production of a zinc oxide assaying nearly 70% zinc.

The method has not been finally worked out as to process difficulties on a production basis, and final costs are not yet available. H. J. R.

*Abstract of "Recovery of Zinc by the Dithionate Sulphur-dioxide Leaching Process", by S. F. Ravitz and A. E. Back, *Journal of Metals*, Nov. 1949, p. 792.

Optical Pyrometer*

VISUAL methods of optical pyrometry normally have a lower limit of usefulness at about 1200° F., but even at this temperature accurate measurements are difficult owing to the low intensity of the light. The possibility of using an image-converter tube in which infrared radiation appears as a visible fluorescent image on a Willemite screen has already been mentioned by T. H. Pratt in *Journal of Scientific Instruments* in 1947. The use of such a system in conjunction with a conventional disappearing-filament optical pyrometer has been reported by the Russian, S. I. Frievert; an accuracy of ±20° is claimed down to 670° F.

In the adaptation shown in Fig. 1, it utilizes a special form of photocell labeled "image-converter tube", in which the anode is replaced by a fluorescent screen mounted in an evacuated cylinder of pyrex with plane end-windows. A photo-cathode (silver-cesium oxide deposit) comprises one window, and the fluorescent screen, placed parallel to it at a distance of about 0.5 cm., is viewed through the other window (transparent). Radiation falling on the cathode releases electrons which are accelerated by a high voltage (6000 volts) to the anode, where they form a green fluorescent image corresponding to the image of the original radiation focused on the cathode. Voltage is supplied from a vibrator power unit working from a 12-volt battery, the unit consuming a current of 350 milliamperes. The fluorescent image is viewed by a magnifying eyepiece.

The straightforward application of the image-converter tube to an ordinary disappearing-filament optical pyrometer as described by Frievert is not very accurate, mainly on account of the unsuitability of optical pyrometer lamps for use at such low temperatures. In the instrument developed at the British National Physical Laboratory, a

(Continued on p. 252)

*Abstracted from "An Optical Pyrometer Employing an Image Converter Tube for Use Over the Temperature Range, 350 to 700° C.", by C. R. Barber and E. C. Pyatt, *Journal of Scientific Instruments* (London), Vol. 27, January 1950.

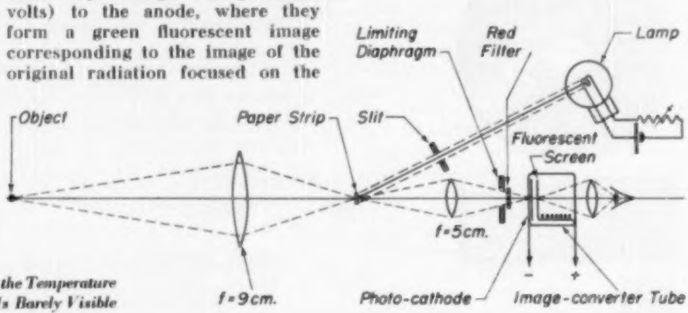

Fig. 1 — Optical Pyrometer for Measuring the Temperature of Objects in the Range Where Radiation Is Barely Visible

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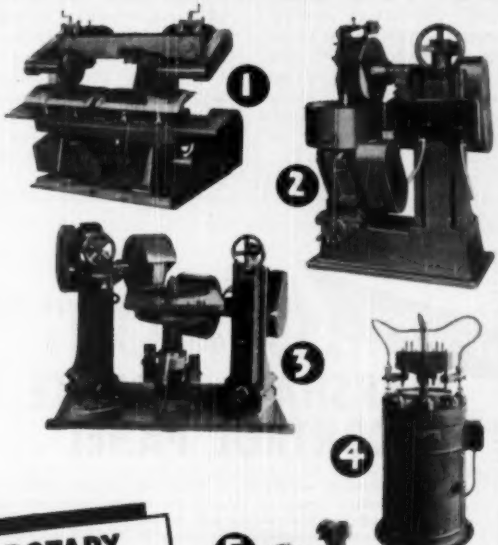

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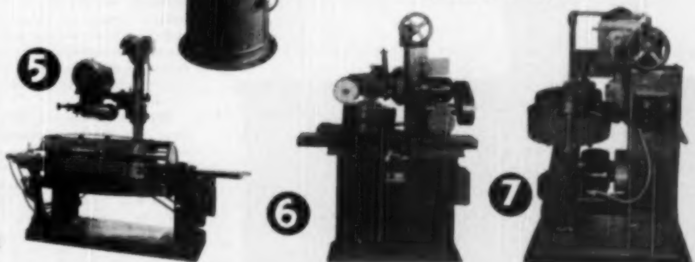

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Optical Pyrometer

(Starts on p. 250)

thin strip of paper, clamped between two glass plates, replaces the lamp filament of the conventional disappearing-filament optical pyrometer. This strip is illuminated from a side tube and is seen through the image-converter tube superimposed on an image of the object. The current through the lamp in the side tube is changed until the strip disappears against the background of the object image, just as in the normal optical pyrometer.

The useful range of this pyrometer is from 670 to 1300° F.; it can be operated as low as 930° F. in a reasonably well-lit room, provided the observer's eyes are shaded from the light. Below that temperature it is still possible to work in a partially lit room, if the observer waits a few minutes for his eyes to become adapted. At 670°, 5 to 10 min. is required before the image can be seen and 15 to 20 min. before satisfactory readings can be made; the readings, however, show no greater spread in terms of temperature than at higher intensities.

The N.P.L. pyrometer was given a trial in the steelworks of Hadfields Ltd., Sheffield, England. Tests were made by sighting the pyrometer on the outside wall of a large hollow cylinder of steel which was being soaked at 950° F. in a gas-fired furnace. The shop was particularly well lit by daylight and the sun was shining brilliantly outside. It was noticed that no observer could get a satisfactory reading until he had been in the shop for upwards of 10 min. If a dark cloth covered the head and eyepiece, reliable readings could be made after 25 sec., and different observers checked each other almost exactly. At 750° F., it was difficult to get a really satisfactory reading.

It is concluded that in the range from 1100° down to 800° F., the image-converter pyrometer as described will be useful in many industrial applications where readings by thermocouples cannot be obtained.

TOM BISHOP

Surface Tension of Liquid Metals

SURFACE TENSION is the force that causes a falling drop of liquid to assume a spherical shape. Liquid metals have higher surface tensions than any other class of liquids, and these high surface tensions can be utilized, for example, in introducing liquid solder alloy between two surfaces that are to be bonded. (A striking application of this property was described on p. 215 of *Metal Progress* for February, where it was shown how a copper brazing alloy would penetrate through a press-fitted joint, around a 180° corner and back through another joint, making a uniform, tight seal around a certain portion of a subassembly.) In powder metallurgy, the infiltration of a compact with liquid metal depends very largely on surface tension. Also, this property is of some importance in the production of castings,

(Continued on p. 258)

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Edited by John T. Burwell, Jr., *Associate Professor*
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Surface Tension

(Starts on p. 252)

though here the effect of true surface tension is likely to be overshadowed by the influence of surface films.

Experimental determinations of surface tension have come almost exclusively from those investigators who are seeking to develop a theory of the liquid state. The forces of attraction among atoms are reflected rather directly in the surface tension; data on surface tension and particularly on its temperature dependence give an indication of the tendency for atoms to cluster in groups or to form molecules in a liquid. Recent experimental work by E. Pelzel of Linz-Leoben, Austria, has provided systematic data that lead to a greater insight into the structure of liquid alloys.★

★"The Surface Tension of Liquid Metals and Alloys", by E. Pelzel, *Berg- und Hüttenmännische Monatshefte*, V. 93, 1948, p. 247-254, and V. 94, 1949, p. 10-17.

For determining surface tension, Pelzel used the "method of maximum bubble pressure", developed by Cantor, Jaeger and Sauerwald.

The results of the investigations with zinc and tin are in good agreement with values previously published by Sauerwald, Bircumshaw, Hogness, Matuyama, Bornemann and Smith. The surface tensions of aluminum and magnesium were determined for the first time; values for the four metals investigated are tabulated in Table I.

Table I — Surface Tension of Zinc, Tin, Aluminum and Magnesium

	M. P., °C.	Surface Tension, α, Ergs per Sq.Cm. at T° C.				
		M.P.	500°	600°	700°	800°
Zn	420	820	800	775	750	725
Sn	232	622	574	556	538	520
Al	660	914	—	—	900	865
Mg	650	559	—	—	542	508

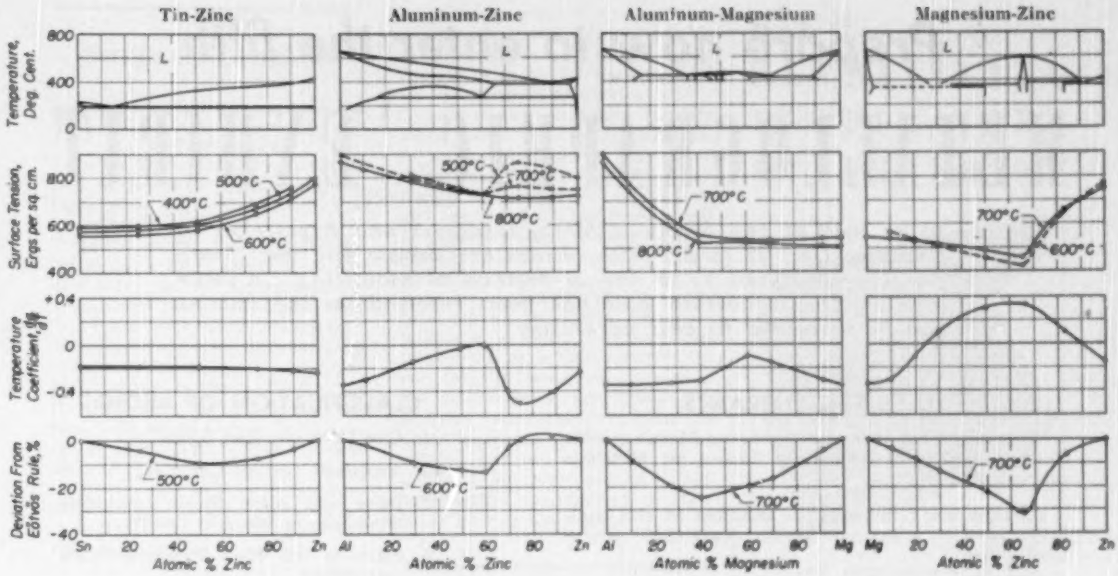
A constant K_E is calculated for the temperature interval from 700 to 800° C. according to the Eötvös formula, and the values for $\frac{d\alpha}{dT}$ using the value $K = 2.12$, which corresponds to the behavior of a "normal" liquid. From the calculation (Table II) it may be seen that three of the temperature coefficients are quite different from the ideal values which correspond to the constant 2.12. Only for magnesium does the $\frac{d\alpha}{dT}$ value approach the ideal value. The calculated K values indicate that liquid magnesium exists as a normal metal but liquid aluminum, zinc and tin are associated — for instance, tin as Sn_3 molecules.

Table II — Temperature Coefficient of the Surface Tension

	Observed $\frac{d\alpha}{dT}$			K_E	$\frac{d\alpha}{dT}$*
	Min.	Max.	Ave.		
Zn	−0.23	−0.27	−0.25	1.56	−0.50
Sn	−0.16	−0.20	−0.18	1.--	−0.38
Al	−0.30	−0.40	−0.35	1.40	−0.50
Mg	−0.14	−0.50	−0.35	2.38	−0.31

*Calculated for a value of $K = 2.12$.

In the second part of his investigation, Pelzel studied the surface tension and the temperature coefficient of binary alloys. He chose two systems forming intermetallic



compounds (aluminum-magnesium and magnesium-zinc) and two systems that do not form intermetallic compounds (tin-zinc and aluminum-zinc).

Isothermal curves of surface tension (second row of graphs above) do not correspond to the law of mixtures, but have considerable deviation from a straight-line relation.

For tin-zinc alloys the maximum deviation is −9.9% at a concentration of 50 atomic % zinc at 500° C. (bottom row of graphs). This indi-

(Continued on p. 261)

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to be held at the National Metal Congress and Exposition in Chicago, Oct. 23 to 27, 1950. Rules are simple and few; there are no restrictions as to size or method of mounting. A large area in the exhibition hall has been reserved so the entries can be displayed to best advantage.

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32nd NATIONAL METAL CONGRESS AND EXPOSITION

October 23-27, 1950

Surface Tension

(Starts on p. 252)

cates the probability of an association to an SnZn complex in the liquid state, which does not exist in the solid state.

In the system aluminum-zinc the atoms form the complexes Al_2Zn_3 and $AlZn_3$, but the aggregation depends very much on temperature.

In the system magnesium-zinc the aggregation of atoms is strongly influenced by the existence of the high-melting compound $MgZn_2$ in the solid state. A similar correlation with compounds in solid aluminum-magnesium alloys is less definite.

Considering all the data for these four binary systems, the author shows that there is no principal difference in the liquid state for the systems with and without intermetallic compounds in the solid state. The difference is only in the magnitude of the effects. There is always more or less tendency toward an aggregation of atoms into stoichiometric groups.

Electroplating Jigs*

NEWER magnetic alloys — for example, those of the alnico family — with 20 times the force of earlier magnets, are proving very valuable for holding steel articles in jigs or on carriers or other fixtures for various finishing operations. An example is in continuous tanks for electroplating. A few major considerations are:

Temperature of operation must not be above that where residual magnetism is lost. The 36% cobalt magnets retain 95% of their magnetism up to 400° F.; alnico up to 800° F.

Attachment to other parts of the jig is apt to be difficult, since some of the magnets are practically unmachinable. Silver soldering is recommended for its strength and electrical conductivity.

Size of magnet should be sufficient not only to carry the load of the part, but also to resist handling stresses — such as the rush of a jet of wash water. For electroplating jigs, the cross section must also be large enough to carry the plating current without deleterious effect on the magnetic properties.

Insulation of magnet (usually U-shaped) from the plating solution, to prevent build-up of deposit, is important. A layer of insulator can usually be placed on the magnet, and removed from the contact area or pole-ends only. At intervals this envelope can be stripped (with any adhering deposits). If the magnet poles are in contact with the article being plated, these areas obviously will have no plate; in some set-ups there may be a gap between the two, current being led away from the article by a conducting peg screwed into a suitable hole. In other instances the magnet may ride clear of the solution — for example in the silver plating of cutlery handles, the blade of the knife being held by the magnet.

*Abstract of "Electroplating Jigs", by A. H. E. Barrow, *Metal Industry*, Feb. 24, 1950, p. 147.

Bright Plate

(Starts on p. 199)

It is made up in the usual fashion, treated with activated carbon and dummied under low current density to remove impurities. It is operated at 60 to 70 amp. per sq.ft. with a PR cycle of 15 sec. cathodic to 3 sec. anodic or, for smoother deposits, 15 to 5 sec. The more sacrificial the cycle, the smoother the deposit. In some cases, even a 15 to 10-sec. cycle is employed. Lower free cyanide and a longer cycle will yield brighter deposits, but a higher free cyanide will provide softer deposits.

It is noteworthy that air agitation is feasible with the use of Wes-X (inorganic) addition agent, producing no excessive foaming, whereas mechanical agitation must be used with organic addition agents to prevent said foaming.

The acid copper bath has always been preferred where throwing power is not an important factor. The use of the PR process with this bath is said to improve greatly both throwing power and speed of plating, and to provide a "leveling" action not characteristic of the usual acid copper bath. Such a bath may be made up as follows:

Copper sulphate	28 oz. per gal.
Sulphuric acid	6.7
Temperature	120° F.

(Continued on p. 262)

Bright Plate

(Starts on p. 199)

It should be filtered free from all suspended matter and maintained clear by continuous filtration. An activated carbon treatment at the start is essential to obtain all the advantages of the process. Addition agents may be used for brighter deposits but such additions may be reduced to ⅛ to 1/10 the amount usually employed. The high-speed acid copper bath requires agitation (preferably by low-pressure blower), continuous filtration, bagged anodes and regular solution purification. Smooth electrodeposits are obtained at current densities up to 200 to 300 amp. per sq.ft. The recommended cycle consists of 9 sec. cathodic to 3 sec. anodic periods, although 2:½ and 15:5 sec. periods have also been used.

Silver Plating Baths—A field in which the PR process has had outstanding success is in silver plating. It has been found that the use of PR with any cyanide silver bath gives smoother, brighter deposits at about twice the speed permissible under continuous current methods.

It is generally known that the final high finish required of silver by the trade can be obtained only by color buffing. However, the deposits obtained by PR are semi-bright or better, and require only a light wipe on the buff to give the desired finish, providing large savings in polishing costs.

A potassium cyanide bath is recommended:

Silver cyanide	4 to 5 av. oz. per gal.
Potassium cyanide (free)	5 to 6 av. oz. per gal.
Potassium carbonate	6 to 8 oz. per gal.

The same precautions as for high-speed plating should be observed. Continuous filtration, solution agitation, bagged anodes and temperatures over 80° F. yield rapid and smooth deposits which, it is reported, have been full bright under certain conditions. The cycle usually consists of a 15-sec. cathodic and a 3-sec. anodic period.

Zinc and Cadmium Baths—PR plating is applicable to both zinc cyanide and cadmium cyanide baths. In some applications, it has been reported, as much as 0.006 to 0.010 in. of metal has been deposited smoothly. A 15:3 sec. cycle is satisfactory and high-efficiency baths have proved to be most satisfactory.

Gold Plating Baths—PR plating has been successful in gold plating heavy deposits without the periodic scratch brushing usually required. Bright deposits are obtainable with proper agitation. A larger cathode-to-anode ratio is required than is true of most other baths, because of the low concentrations generally used in gold baths and their cathode efficiency of less than 100%. When anodic, the bath efficiency is much greater; therefore, a relatively long cathodic time is necessary. A 7:1 sec. cycle has been found satisfactory for a bath containing 0.6 oz. per gal. gold.

Nickel Plating Baths—It has been found that periodic reverse plating has a definite leveling action on nickel deposits and that bright deposits can be obtained without addition agents. The process can also be used with proprietary brighteners in which the amount of brightener may be reduced to 1/10 of the amount formerly used.

Applications

Periodic reverse plating, like bright plating baths, is not recommended for all operations; nor is it the "cure-all" for the plater's troubles. However, it has a variety of important applications.

Heavy coatings of smooth, fine grained copper may be deposited in a relatively short time. Wire has been plated to a thickness of 0.006 in. at current densities above 100 amp. per sq.ft., and the deposit is characterized by an exceptionally high conductivity. Magnets have been plated with copper to a thickness of 0.012 in. in 2 hr., also with excellent conductivity. Phonograph record stampers have been produced to a thickness of 0.030 to 0.050 in. with not only a smooth surface, but the proper taper as well. Using the cyanide bath, plating time has been halved and stamper life improved. Printing rolls (rotogravure) have been copper plated to the usual 0.006 in. with smooth, dense, wear resistant coatings.

In general, it is felt that where heavy deposits are desired from alkaline baths, the use of the periodic reverse plating should be considered.

Die castings are being plated in large numbers; full bright to semi-bright copper deposits are obtained. This is especially advantageous in view of the trend toward thicker

deposits and more stringent specifications.

Steel stampings can be put through the full plating cycle with a minimum of wheel or mechanical finishing. In one instance, by choosing a good grade of steel, it was possible to copper plate, using a sacrificial cycle (15:10) for 1 hr. to yield a 0.0014-in. copper deposit which gave a Brush oscillograph RMS reading of 7 micro-in. The original surface of the steel gave an RMS reading of 35. This spectacular improvement in surface smoothness makes it possible to apply bright nickel and chrome directly after copper plating.

Sometimes the chromium has been plated directly over the copper, with great improvement in the ability of the chromium to "throw". An interesting example was an automobile bumper section, plated in production, where the original steel surface of about 50 micro-in. smoothness was plated with copper, nickel and chromium by this process; and without conforming anodes, the chromium plate at the end was bright enough to reflect one's features with considerable clarity. In another example, the cover for a waffle iron had considerable chromium plate clear around on the inside of the stamping, even beyond the points where it was wanted.

Conclusions

The possible benefits obtainable from the application of PR process include the following:

1. Use of higher current densities; consequently, faster plating.
2. Improved brightness of the deposit.
3. Improved smoothness over that of the basis metal.
4. Heavier deposits obtainable.
5. Ductile deposits with controllable hardness.
6. Reduction of porosity normally present.
7. Higher throwing power with better metal distribution.
8. Improved anode corrosion.
9. Elimination of organic addition agents and greater tolerance to impurities.

It should be pointed out that all of the above benefits are not obtainable at their maximum at any one time. For example, maximum smoothness is obtainable with a highly sacrificial cycle; maximum rate of plating results from the least sacrificial cycle recommended.

The best deposits are obtained in the potassium baths. Sodium salts or combination sodium-potassium solutions can be employed with good results, but superior deposits and plating rates are obtained with the all-potassium baths. Sodium baths may be readily converted to potassium if so desired.

In some instances, the cost of PR plating is higher than continuous-current plating but these increases may be more than offset by reductions in polishing and other mechanical operations, resulting in a reduced over-all cost. For example, Jernstedt cites a part costing 37¢ in the completed form when treated by the conventional method and 23¢ when PR plated. The plating costs were increased from 2¢ to 4¢, but at the same time buffing and polishing costs were reduced from 28¢ to 14¢.

Another application of this process is a washing machine door, on which the operations consisted of: *(a)* stamping, *(b)* removing fins, *(c)* cleaning, *(d)* copper plating, and *(e)* bright nickel plating.

In general, there was no buffing or coloring, although in some applications, coloring was necessary in order to maintain the high degree of luster required. Before plating, the surface was 35 micro-in.; and after copper plating, the surface was 7 micro-in. The cycle was 15 sec. plating and 10 sec. deplating at a current density of 60 A.S.F., and a plating time of 1 hr. to deposit 0.0014 in. of copper. In spite of the long plating time, the operation saved money.

Cost Analysis

Jernstedt cites a detailed cost analysis for the production of one highly polished part, both by direct-current and periodic reverse-current electroplating, as follows:*

	Direct Current	Periodic Reverse Current
Burr and Brush	$0.0313	$0.0313
Polish Edges	0.0300	—
Polish Top	0.0093	—
Spot Polish	0.0093	—
Copper Plate	—	0.0300
Copper Polish	—	0.0600
Nickel Plate	0.0246	0.0200
Nickel Buff	0.0786	—
Nickel Color Buff	0.0235	0.0235
Chrome Plate	0.0139	0.0139
Chrome Color Buff	0.0246	0.0246
Total Plating and Finishing	$0.2451	$0.2033
Unplated Part	0.0946	0.0946
Total Cost	$0.3397	$0.2979

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